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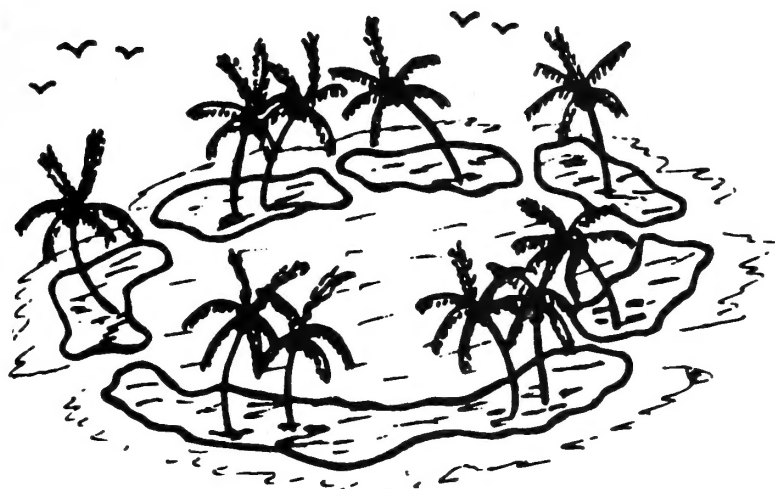
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ATOLL RESEARCH BULLETIN

241. *Geography and Ecology of Little Cayman*
Edited by D.R. Stoddart and M.E.C. Giglioli



Issued by
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Washington, D.C., U.S.A.

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ATOLL RESEARCH BULLETIN

No. 241

GEOGRAPHY AND ECOLOGY OF LITTLE CAYMAN

Edited by D.R. Stoddart and M.E.C. Giglioli

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March 1980



Plate 1. The south coast of Little Cayman, from the southeast; noon cumulus extending along the length of the island

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1. SCIENTIFIC SURVEY OF LITTLE CAYMAN

D.R. Stoddart

Introduction

Little Cayman (Plate 1) is the smallest of the three Cayman Islands, emergent sections of the Cayman Ridge along the northern margin of the Cayman Trench between the Sierra Maestra of Cuba and the coast of Belize. The Trench itself is 1700 km long, and has maximum depths south of the Cayman Islands of more than 6000 m. Little Cayman lies 230 km from Cabo Cruz, Cuba; the same distance from the nearest point of Jamaica; and 740 km from the mainland of Yucatan. The Caymans themselves are well separated from each other: Little Cayman is 117 km ENE from Grand Cayman, though only 7.5 km from Cayman Brac (Figure 1).

The island itself is 16.3 km long and 1.1-2.9 km wide. It has a total land area of 28.5 sq km (compared with 197 sq km for Grand Cayman and 38 sq km for Cayman Brac). It is also the lowest. Its highest point is 14 m, but only 3.7 sq km or 13 per cent rises above 6 m (compared with 21 per cent for Grand Cayman and 76 per cent for Cayman Brac).

Rainfall records have only been maintained on Little Cayman since the end of 1970, as part of the Mosquito Research and Control Unit Cayman Islands network. The two stations are both at the west end of the island (963738, 945754). The records (Table 1 and Figure 2) show considerable year-to-year variation in totals (from 800 to nearly 1900 mm), though the long-term mean is probably about 1400 mm. There is a dry season from November to April, and a wet season from June to October, though the records show considerable variability. The low, seasonal and uncertain rainfall combined with the dissected limestone terrain and predominantly scrubby vegetation gives an impression of an arid and inhospitable environment.

Table 1. Rainfall records at Little Cayman (mm)

	<u>Jan</u>	<u>Feb</u>	<u>Mar</u>	<u>Apr</u>	<u>May</u>	<u>Jun</u>	<u>Jul</u>	<u>Aug</u>	<u>Sep</u>	<u>Oct</u>	<u>Nov</u>	<u>Dec</u>	<u>Year</u>
<u>Blossom Village (963738)</u>													
1970	-	-	-	-	-	-	-	-	-	-	135.9	8.1	-
1971	25.4	107.4	16.0	0	69.6	160.5	131.8	222.3	105.9	315.2	677.2	41.4	1872.7
1972	36.3	30.0	32.0	39.1	71.9	260.6	71.9	99.6	237.5	173.7	47.8	220.2	1320.5
1973	14.0	3.6	12.5	9.4	54.1	163.8	93.2	176.0	95.3	185.4	63.0	28.4	898.7
1974	25.4	0	8.2	27.7	151.1	42.9	54.1	88.9	208.8	326.9	22.8	32.3	989.3
1975	27.4	34.5	23.1	28.4	55.1	55.9	143.8	63.0	192.8	86.9	70.9	24.9	806.7
1976	77.7	32.3	25.4	61.5	99.8	418.1	20.6	52.3	97.5	127.5	102.1	-	-
Mean	34.4	34.6	19.5	27.7	83.6	183.6	85.9	117.0	156.3	202.6	160.0	25.9	1177.6

Spot Bay (945754)

1975	-	-	-	40.4	70.4	46.5	162.8	7.4*	175.8*	68.3	99.1	21.6	-
1976	37.6	11.7	9.4	-	80.3	557.8	2.0*	22.9	-	152.7	66.0	-	-

*two weeks only

No other climatic data are available for Little Cayman, but conditions are probably similar to those of Grand Cayman (Darbyshire, Bellamy and Jones, 1976). Highest temperatures on the larger island occur during the wet season (with mean daily temperatures in August reaching 29.5°C) and lowest in the dry (mean daily temperatures in January 26°C); diurnal temperature range is about 5.5°C.

Winds are dominated by the Northeast Trades. About 71 per cent of observations are in the sectors 030-090°. This dominance is most marked during the winter; in the summer, southeasterlies may occur. On occasion during the winter months 'Northwesters' of several days' duration bring stormy weather, rainfall, and reduced temperatures, with north and northwesterly winds commonly reaching 13 m/sec (25 knots). Modal wind speeds during normal conditions are approximately 5m/sec (about 10 knots).

The Cayman Islands lie within the zone of catastrophic hurricanes. There are few records of their occurrence at Little Cayman itself, but more than 40 have been recorded in the group since 1751 (Williams 1970; Woodroffe, *in litt.*). The variable frequency over this period is only partly attributable to gaps in the historical record, and it appears that storms were most numerous during 1895-1903, 1909-1917, and 1932-1944. From the records at Cayman Brac, Little Cayman probably experienced major hurricanes in 1912, 1915, 1932 and 1935; the great storms recorded at Grand Cayman in 1785, 1837, 1838, 1846, 1876, 1903, 1909, 1915 and 1917 may or may not have been equally damaging in the Lesser Caymans. The effects of such storms include: torrential rainfall (up to 30.5 cm/24 hours on Grand Cayman); wind damage to vegetation, especially mangroves; inundation by storm surge; mechanical damage to coral reefs and other marine communities; and construction of beach ridges and deposition of coral boulders and rubble in nearshore areas. Hurricanes have probably also been important agents in bringing plant and animal colonists to the islands from the Greater Antilles.

Ocean currents in the Cayman area are mainly from the southeast. Evidence collated during the Cayman Islands Natural Resources Study, however, suggested the possibility of variable currents in the area between the Caymans, Cuba and Jamaica, giving intermittent surface flows from west to east and possibly from the north as well. Velocities of the dominant easterly currents near Grand Cayman averaged 30 cm/sec during this Study, and exceeded 35 cm/sec for nearly 20 per cent of monitoring time (Darbyshire et al., 1976). With such velocities drifting propagules would take some 210 hours (approximately 9 days) for the journey between Little Cayman and either Cuba or Jamaica.

Little Cayman shares many characteristics in common with other similar small limestone islands in the Caribbean, some of which have been more fully studied and are better known. These include Barbuda, Anguilla and especially Anegada. Anegada is very nearly the same size as Little Cayman: it is 16 km long and 3.6 km wide, and has an area of 33 sq km; its maximum height is 4.5 m. Both islands have a flora of about 240 species (D'Arcy 1975; Proctor, this volume). Anguilla and Barbuda have areas of 90 and 160 sq km, and annual rainfalls of 1143 and

990 mm, respectively (Harris 1965).

Scientific studies

Little Cayman was discovered on 10 May 1503 by Columbus; it was not permanently settled until 1833, and the population (which was 23 at the 1960 census and 20 in 1970) has always been small. Scientific knowledge began when the island was charted by H.M.S. *Sparrowhawk* in 1880. This chart, with revisions, is still current (Admiralty Chart 462: 1:72,630). Many existing placenames were established during this survey.

Attention was first directed to birds. C.J. Maynard collected there in 1888, and a list of Little Cayman birds was published by Cory (1889). Other ornithological visitors included P.R. Lowe on the *Emerald* in January 1904, and M.J. Nicholl on the *Valhalla* in March the same year. Lowe (1911) subsequently included many Little Cayman records in his list of Cayman Islands birds. Other ornithological collections on Little Cayman have been made in 1911 by W.W. Brown (Bangs 1916), in 1938 by C.B. Lewis, in 1956 and 1958 by C.H. Blake, in 1961 by A. Schwartz (Schwartz and Klinikowski 1963), during 1965-1971 by D.W. Johnston, and in 1969 by R. Pulliam. These records were included in the listing of birds of the Cayman Islands by Johnston, Blake and Buden (1971) and in the ecological account by Johnston (1975).

Maynard also collected the first Little Cayman reptiles, which were reported by Garman (1888). New records were added by English (1912). P. Bartsch made a collection in 1930 (Conant 1934), while working on the land molluscs, and A. Carpenter added a further record (Conant 1937). These were the only reptile collections before 1938.

C.A. Matley spent two days on the island in 1924, studying the geology, producing a remarkable paper (Matley 1926). Many other investigators who collected or observed on the two larger Cayman Islands in these earlier years, failed, however, to reach Little Cayman (bibliography in Stoddart, in press).

Our main source of information on the fauna and flora of Little Cayman, as indeed of the group as a whole, remains the work of the Oxford University Expedition to the Cayman Islands in 1938, led by W.G. Alexander. This Expedition spent the period 28 May to 10 June on the island, and large collections were made under what must have been very difficult conditions before any roads had been made. The reptiles were reported by Grant (1940) (reviewed by Williams 1969), the land Mollusca by Pilsbry (1942), and the marine Mollusca by Salisbury (1953). W.W. Kings collected plants, and though no list was published his specimens have been incorporated in G.R. Proctor's *Flora of the Cayman Islands*, now in press. Large insect collections were made, and the literature on these is keyed in Table 2.

Table 2. Publications on insects of Little Cayman arising from the Oxford University Expedition to the Cayman Islands in 1938

Odonata	Fraser 1943
Hemiptera	Hungerford 1940
Neuroptera	Banks 1941
Lepidoptera	Jordan 1940; Carpenter and Lewis 1943
Coleoptera	
Carabidae	Darlington 1947
Cerambycidae	Fisher 1941, 1948
Scarabidae	Sanderson 1939
Staphylinidae	Blackwelder 1947
Homoptera	Davis

Subsequently, though individual workers made brief visits, there has been no comparable general survey. The present study, which formed the Royal Society and Cayman Islands Government Expedition to Little Cayman, extended from 11 July to 11 August 1975, and included the following personnel:

D.R. Stoddart (Cambridge): geomorphology, leader
 R.R. Askew (Manchester): entomology
 A.W. Diamond (Nairobi): ornithology
 G. Giglioli (Georgetown): marine studies and liaison
 M.V. Hounscome (Manchester): land fauna other than insects
 G.W. Potts (Plymouth): marine ecology
 G.R. Proctor (Kingston): botany
 C. Woodroffe (Cambridge): mangroves (part-time).

The Expedition was sponsored jointly by the Royal Society of London and the Cayman Islands Government, and was planned jointly by Stoddart and Dr M.E.C. Giglioli, Director, Mosquito Research and Control Unit, Grand Cayman. It arose from the work of the Natural Resources Study initiated on Grand Cayman, and can be regarded as part of a continuing natural resources survey programme in the Cayman Islands. The field party was joined from time to time by staff members of the Mosquito Research and Control Unit, notably E. Parsons and R. Todd.

The purpose of the Expedition was to define and characterise the major terrestrial and shallow marine habitats of the islands, and to describe the major features of the marine and terrestrial biota in relation to them, thus providing data which could form the background for management decisions in the event of any proposals for major

industrial and commercial development. The period of investigation was only one month, and appeared to coincide with unprecedented mosquito activity. Accessibility was largely limited to tracks and to traces cut in 1974 by the Cadastral Survey of the Cayman Islands. Large areas remained unvisited, though aerial photograph interpretation suggests that all major habitats were sampled. The present series of papers summarises the main work of the Expedition.

Acknowledgements

This Expedition was made possible in the first instance by the initiative of the Government of the Cayman Islands, and we are indebted to successive Governors, Mr K.R. Crook and Mr T. Russell, and many members of the Administration, notably Mr W. Conolly, for their support. The programme was organised and partly funded by the Royal Society of London, through its Southern Zone Research Committee under its chairman, Sir Maurice Yonge. The investigation forms part of an enquiry into the natural resources of the Cayman Islands organised by Dr J.H. Wickstead and Dr M.E.C. Giglioli. Scientific studies in the Cayman Islands in general, and this project in particular, owe an enormous debt to the enthusiasm and expertise of the Mosquito Research and Control Unit, whose Director, Dr Marco Giglioli, with Mrs Giglioli, did so much on scientific, logistic, and social levels to ensure the success of the Expedition. We are also grateful to Dr Wickstead and to Mr Martin Brunt of the Land Resources Division, Ministry of Overseas Development, for much assistance in planning and organisation.

The study of Little Cayman was ultimately made possible by the great generosity of Dr Logan Robertson, of Asheville, North Carolina, who made his home at Pirate's Point available as the Expedition's headquarters in 1975. We owe a great debt to him and to all the people of Little Cayman for their assistance. The Mosquito Research and Control Unit made available vehicles, boats, and supplies to supplement those brought from London, and we acknowledge the consideration of the Cayman Islands Government in allowing us to import our cargo free of customs duty.

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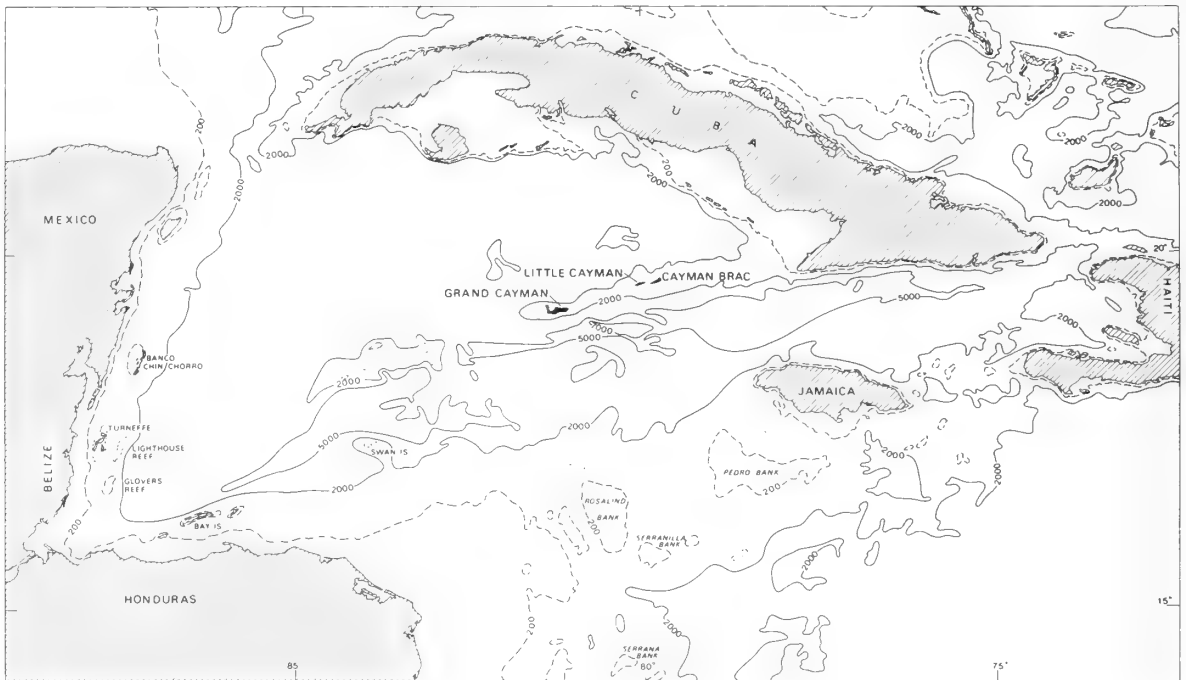


Figure 1. Location of the Cayman Islands

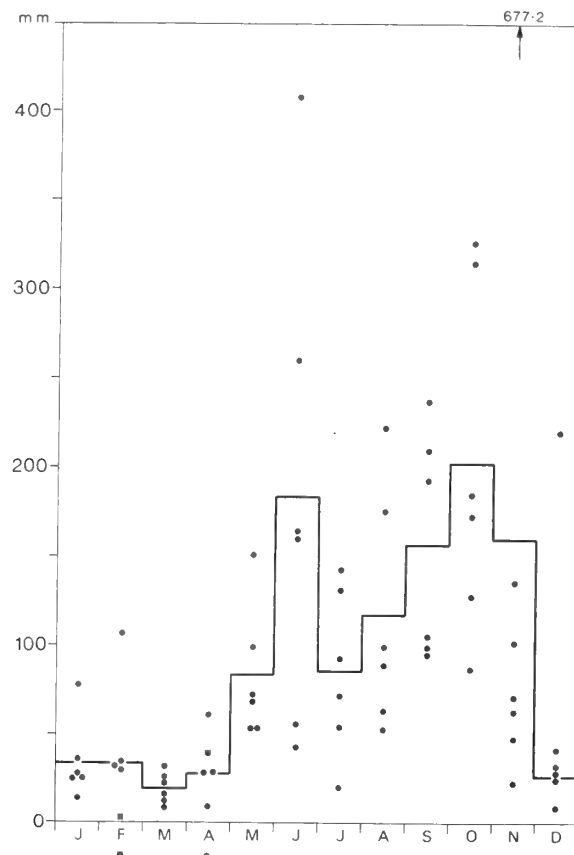


Figure 2. Monthly rainfall at Little Cayman

2. GEOLOGY AND GEOMORPHOLOGY OF LITTLE CAYMAN

D.R. Stoddart

Introduction

Little Cayman forms one of the emergent islands along the northern rim of the Cayman Trench, between the Sierra Maestra of Cuba and the Gulf of Honduras. The Trench itself is 1700 km long and more than 100 km wide (Uchupi 1975). It includes the Oriente, Bartlett and Misteriosa Deeps, all reaching more than 6000 m depth. The nearest land areas to the Cayman Islands (other than Cuba), such as Jamaica and the Swan Islands, lie on the southern side of the Trench.

Early workers such as Taber (1922) considered the Trench to be the site of massive lateral movement. Such views have had to be modified in the light of plate tectonic theory, though some workers still envisage lateral movement along it of up to 1000 km. It is known that granodiorites outcrop in the walls of the Trench at depths of 600-3400 m, and geophysical data suggest a possible tensional origin. Spreading rates have been inferred of 0.4 cm/year since the Eocene, accounting for 200 km of left-lateral displacement between the Cayman Ridge and the Nicaraguan Plateau (Perfit and Heezen 1978); other workers suggest greater rates of spreading (Macdonald and Holcombe 1978). The Cayman Islands themselves probably have a granodiorite foundation, capped by basalt, and overlain by mid-Tertiary and later carbonates. Perfit and Heezen (1978) suggest a general subsidence rate of 6 cm/1000 years during the carbonate accumulation, but the exposure of marine limestones in each of the Cayman Islands indicates local uplift. Unpublished work on the late Quaternary shorelines of all three Cayman Islands (Woodroffe and Stoddart, *in litt.*) indicates that Grand Cayman, Cayman Brac and Little Cayman have each moved independently with respect to sea-level over the last 100,000 years.

Rock units and landforms

Matley (1926) defined two main lithologic units in the Cayman Islands: the Bluff Limestone of mid-Tertiary age and the Ironshore Formation of Pleistocene age. Matley visited Little Cayman and produced a small-scale geological sketch map, indicating that the eastern half of the island consisted of Bluff Limestone, with a narrow peripheral belt of Ironshore, and the western half consisted entirely of Ironshore. As he described it, the Bluff Limestone formed a "highly honeycombed limestone corroded into jagged needles of rock and covered with irregular holes, sink-holes and fissures", and consisted of "hard white recrystallised limestone", probably of Miocene age (Matley 1926, 363-365). It was inferred that the Bluff Limestone reached a maximum height of 45 ft (14 m) at Weary Hill. The Ironshore Formation in the west consisted of a lower reef facies overlain by bedded limestone reaching 10-12 ft (3-3.7 m) above sea level. The boundary between the Bluff Limestone and the Ironshore Formation on Matley's map was tentative.

No further geological observations were made on Little Cayman until those of Mather (1971). He too distinguished the Bluff Limestone and the Ironshore Formation. He described the Bluff Limestone reaching a general maximum height of 20 ft (6 m), with a peripheral ridge reaching 40 ft (12 m) in places. The distribution of Bluff Limestone as mapped by Brunt *et al.* (1973, 212) resembled that shown by Matley. The Ironshore Formation was studied in greatest detail by Brunt *et al.* on Grand Cayman, where it was differentiated into reef, back-reef, lagoonal, shoal, and beach-ridge facies. In their treatment of Little Cayman, reef and back-reef facies were not specifically mentioned, but it was noted that lagoonal facies were of limited extent. They also identified "at a number of localities on ... Little Cayman ridges of calcarenite attaining elevations of over 7 m above sea level", and commented that "these rocks generally overlies sediments of lagoonal facies" (Brunt *et al.* 1973, 214). On Grand Cayman similar ridges consist of cross-bedded colites and are interpreted as submarine sand ridges formed in a lagoonal environment. Some of these ridges are shown diagrammatically in a geological sketch map of Little Cayman (Brunt *et al.* 1973, 212).

Neither Matley nor Brunt *et al.* apparently had much opportunity to traverse the island, or to relate the characteristics of rocks at outcrop to topographic features. More detailed study has been made possible by the publication of the Directorate of Overseas Surveys (D.O.S.) topographic map at 1:25,000, based on photogrammetry, with contours at 20 ft (6 m) intervals and some vegetation interpretation by the installation of a series of coastal benchmarks by D.O.S., most of which could be relocated in 1975; by the cutting of a network of trans-island traces by the Cadastral Survey of the Cayman Islands, mainly during 1974; and by the mobility made possible by the construction of a road round much of the coast in 1973. Aerial photographs are also available at a scale of 1:12,500, though these were flown in 1958 before the cadastral traces were cut.

The 1:25,000 topographic map clearly delineates a discontinuous series of narrow ridges (Figure 3; Plates 2-4) round the periphery of the island, immediately inshore of the coastal ponds and salt flats; they are defined by the 20 ft (6 m) contour, and isolated small sections reach 40 ft (12 m). Using this map and the aerial photographs an attempt was made so far as possible to define the relative extent of the formations described by Matley and Brunt *et al.* Where possible instrumental surveys were carried inland from the coast to establish elevations with respect to sea level. Figure 4 shows the main traverses made: it is clear that large areas of the interior were not visited directly, and the aerial photographs were used to extrapolate between traverses.

Two main features were mapped during the traverses. The Bluff Limestone was recognised (a) by its highly dissected surface topography, with pits, pinnacles, deep holes, and occasional collapse dolines leading into caves (Plates 5-8), and (b) by its appearance in hand specimen as a dense, white, extremely hard, largely structureless limestone. Veins and sheets of crystalline calcite occupying joints and bedding planes are common, as are irregular patches of tightly lithified and occasionally brecciated yellow and brown pipe-fill deposits. "Caymanite", finely bedded impure dolomitic limestone ranging in colour from white through red and brown to black, was never found on Little Cayman, though characteristic of Bluff Limestone, apparently as a fissure-fill, on both Grand Cayman and Cayman Brac. Otherwise the Bluff Limestone closely resembles that on the two larger islands, at least in hand specimen and topographic expression. On Little Cayman, Bluff Limestone outcrops on the coast only at the east end, where it forms ramp-like cliffs (Plate 9).

The second extensive unit on Little Cayman is interpreted as a Marl or Sand Ridge Facies of the Ironshore Formation. In hand specimen it is a fine-textured cream to buff limestone, massive, structureless, and usually lacking fossils. It forms a solid surface and in contrast to the Bluff Limestone often carries a soil and litter cover. In the western lowlands the surface is undulating, with a relief of 0.5-1 m, with red or yellow soils, often phosphatic, in the swales. In the central part of the island, south of Sparrowhawk Hill, the surface is more uniform and the soils darker, deeper and more continuous. This unit also forms the high peripheral ridges, reaching a height of 13 m above sea level, though some ridges, especially those in the northeast, are formed of Bluff Limestone. Ridges formed of Sand Ridge facies have undissected surfaces, and soil is present though thinner than in the lowlands. In hand specimen lithology appears similar irrespective of altitude.

The field relations of the two units are not easy to interpret. Little Cayman differs from Grand Cayman and Cayman Brac, where there is a high core of Bluff Limestone surrounded by an apron of Ironshore Formation. On Little Cayman the Sand Ridge facies of the Ironshore appears to penetrate into the centre of the island between ridges of dissected Bluff Limestone. The highest areas surveyed consist of Sand Ridge facies, but conversely there are large areas of dissected

Bluff Limestone which are not covered by the Sand Ridge or Marl Facies. The transition between the two units is often very abrupt, especially in interior depressions near present sea level. On field relations alone it is often impossible to be certain whether interior karst-eroded depressions consist of Bluff Limestone surrounded by Ironshore or of dissected Ironshore itself.

The Reef Facies of the Ironshore Formation outcrops to form coastal platforms at Salt Rocks and immediately south of the airstrip at the west end of the island. It is also found on the seaward side of Owen Island in South Hole Sound, but is absent from the rest of the south coast. There are low discontinuous exposures on the north coast at Bloody Bay, and at the east end at Calabash Spot (Figure 5; Plates 10-12). In addition to these coastal platforms, corals (mainly *Montastrea* species) are also almost always found in limestone below about 1.5 m above sea-level on the landward margins of salt ponds and salt flats (Plate 13), and this may represent the inner edge of the Reef Facies where it either abuts against Bluff Limestone or passes into back-reef facies. The upper surface of the Reef Facies proper stands at less than 2 m above sea level at all locations. It is highest at Salt Rocks, where it reaches 1.9 m; elsewhere it stands at less than 1.5 m and often less than 1 m above sea level. Where higher elevations are found these are on Sand Ridge Facies rather than Reef Facies.

The coral fauna is modern, and the same as that of Grand Cayman. Common components at Salt Rocks are:

<i>Acropora palmata</i>	<i>Montastrea annularis</i>
<i>Diploria labyrinthiformis</i>	<i>Montastrea cavernosa</i>
<i>Diploria strigosa</i>	<i>Porites porites</i>
<i>Meandrina</i> sp.	

In the south, the dominant coral is *Montastrea annularis*, though *M. cavernosa* is also present. *Strombus gigas* is conspicuous and locally common.

The upper surface of the Reef Facies is horizontal, though deeply dissected in places by potholes (Plate 14); its inner part may be exfoliating and smooth. It is probably a depositional rather than erosional surface.

The contact between the Reef Facies and the Sand Ridge Facies is best seen at Salt Rocks (935745: Figure 6; Plates 15-16). Here the horizontal Reef Facies surface is overlain by bedded calcarenites 2 m thick at their outer edge. The upper surface of the calcarenite rises from 4 to 5 m above sea level in a distance of 25-35 m before passing beneath a Recent boulder beach; inland of the boulder beach the surface continues to rise and reaches a height of 13 m at 300 m from the sea (Figure 4A). The unit has three components: a basal coarse grit with rounded blocks of oolite and *Strombus* shells; a bedded calcarenite showing strong seaward dip; and an upper gently dipping calcarenite forming the ground surface. Similar bedded oolitic calcarenites overlie Reef Facies in a comparable location on Grand Cayman (at 589325).

By comparison with similar reefs on other Caribbean islands, the Reef Facies of the Ironshore Formation is probably of last interglacial age (ca 125,000 yr). The associated facies are probably of broadly comparable last interglacial age, though on both Grand Cayman and Little Cayman the Sand Ridge Facies presents problems of interpretation and chronology.

The peripheral Recent beach ridges (Figure 7; Plates 17-19) are variable in height, width and composition on Little Cayman. The cobble and rubble ridge at Pirate's Point (943738) is 100 m wide and reaches 4 m above sea level; it is one of the largest on the island. Sand ridges and mixed sand and cobble ridges are usually smaller. At the West Point light (933743) the ridge is 55 m wide and 3.7 m high; at Blossom Village (960738) the dimensions are 50 m and 2 m; at Paradise End (046777) 120 m and 2.9 m; and at Sparrowhawk Hill (004785) 50 m and 1.7 m. All these are asymmetric ridges, highest near the sea and declining to a salt pond or salt flat on the landward side. In some protected situations, as at Bloody Bay (973768), however, the ridge is low and featureless, forming a horizontal surface 150 m wide and 1.5 m high. All these ridges are probably built on a platform of Ironshore Formation at or slightly below sea-level, and in most cases this platform outcrops on the landward side as the rock floor of salt ponds and salt flats. The sand and cobble ridge at Salt Rocks is unusual in that it is perched on high-standing Ironshore about 80 m from the sea; it is about 35 m wide and 2.7 m thick. From Mary's Bay to Calabash Spot on the northeast coast, the modern beach ridge directly abuts the Bluff Limestone Cliff; there are no salt ponds or flats, and the height of the sand ridge is increased by dune deposits. The ridges are wholly formed of reef-derived carbonates, with the exception of locally abundant patches of drift pumice.

The cobble and rubble ridges are clearly localised formations attributable to major storms; it is noteworthy that they are all single features rather than sequences of ridges. There are also some large storm blocks, especially on the southern Ironshore platform near the airstrip (Plate 21). Two large blocks here measured 1.2 x 1.5 x 1.5 m and 1.8 x 1.5 x 1.5 m.

The sand ridges consist of well-sorted carbonate sands in the coarse to medium sand categories (Figure 8). Beachrock is not common on the present beaches, but relict beachrock is quite extensively exposed a few metres from the beach foot along the south coast.

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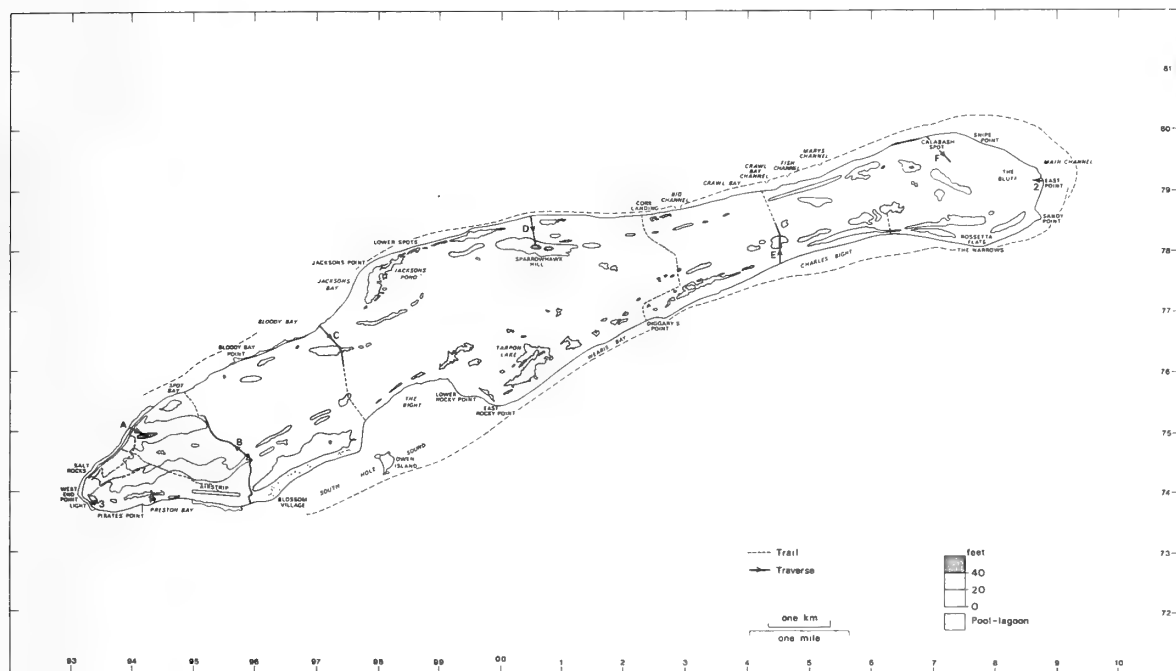


Figure 3. Topography of Little Cayman, based on the Directorate of Overseas Surveys 1:25,000 map (1965)

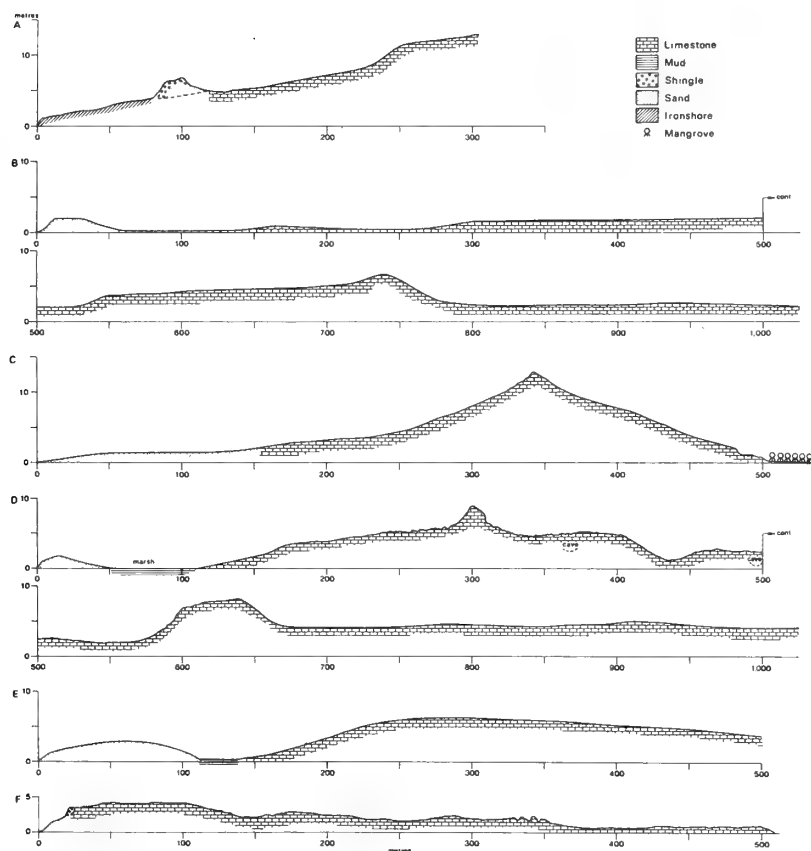


Figure 4. Topographic traverses A-F: for locations see Figure 3



Figure 5. Geology and habitats of Little Cayman

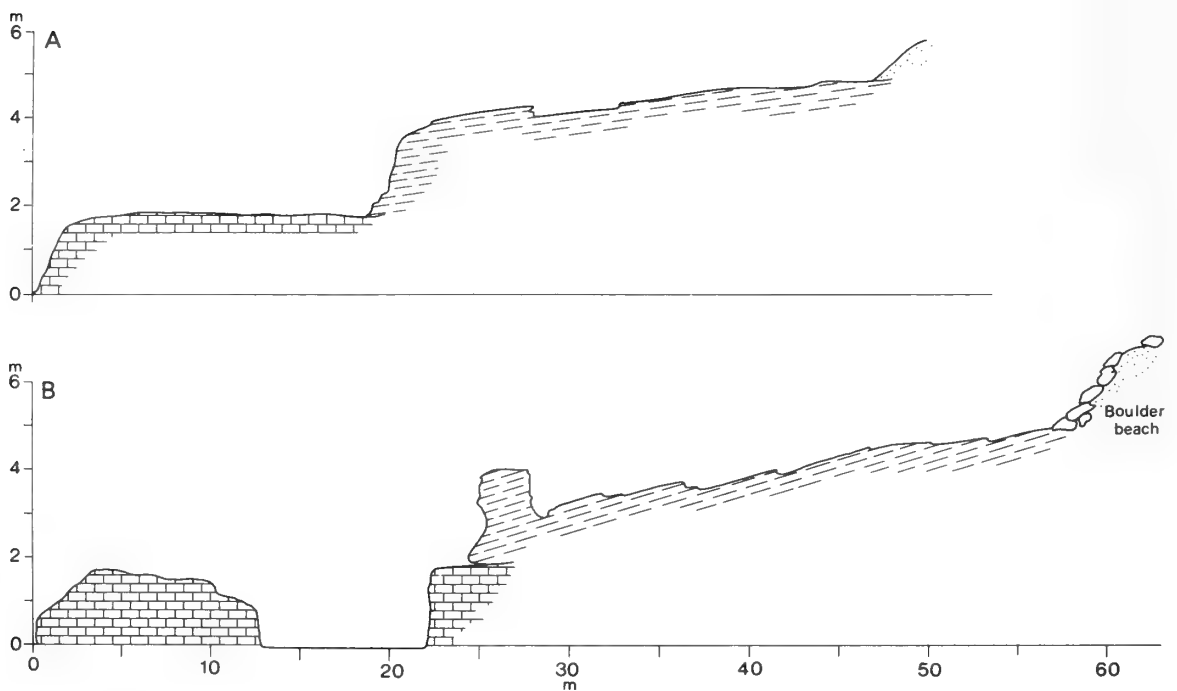


Figure 6. Topographic profiles at Salt Rocks

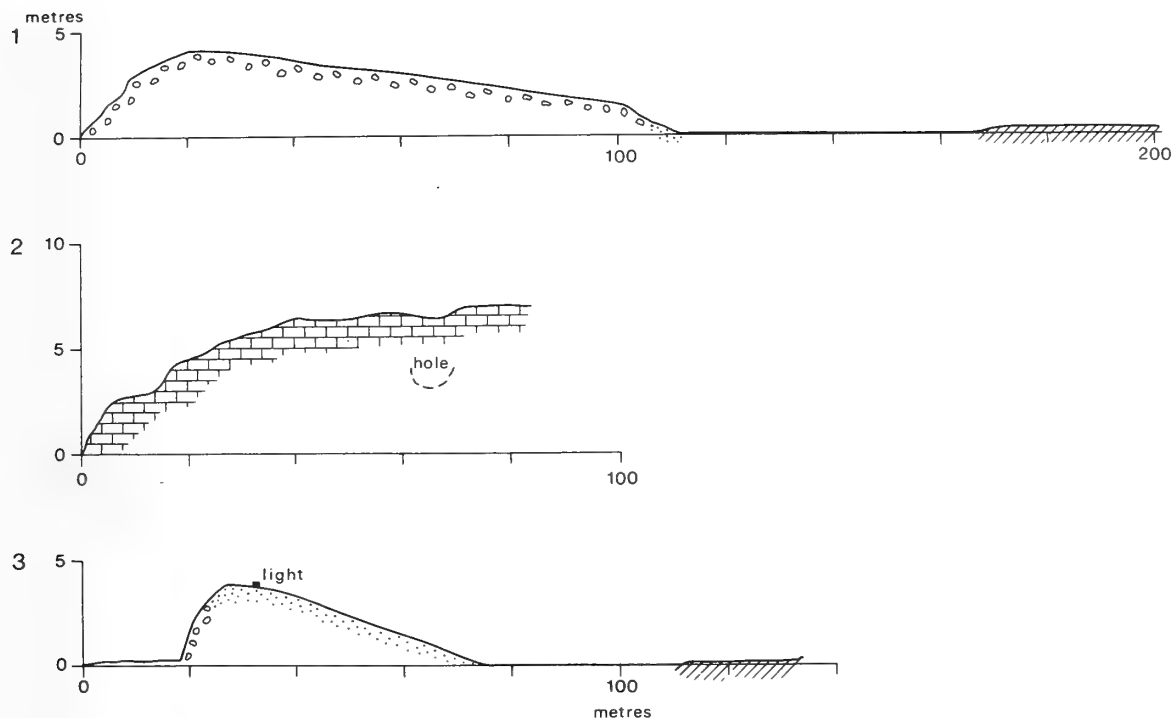


Figure 7. Beach ridge and cliffed coast profiles: for locations see Figure 3

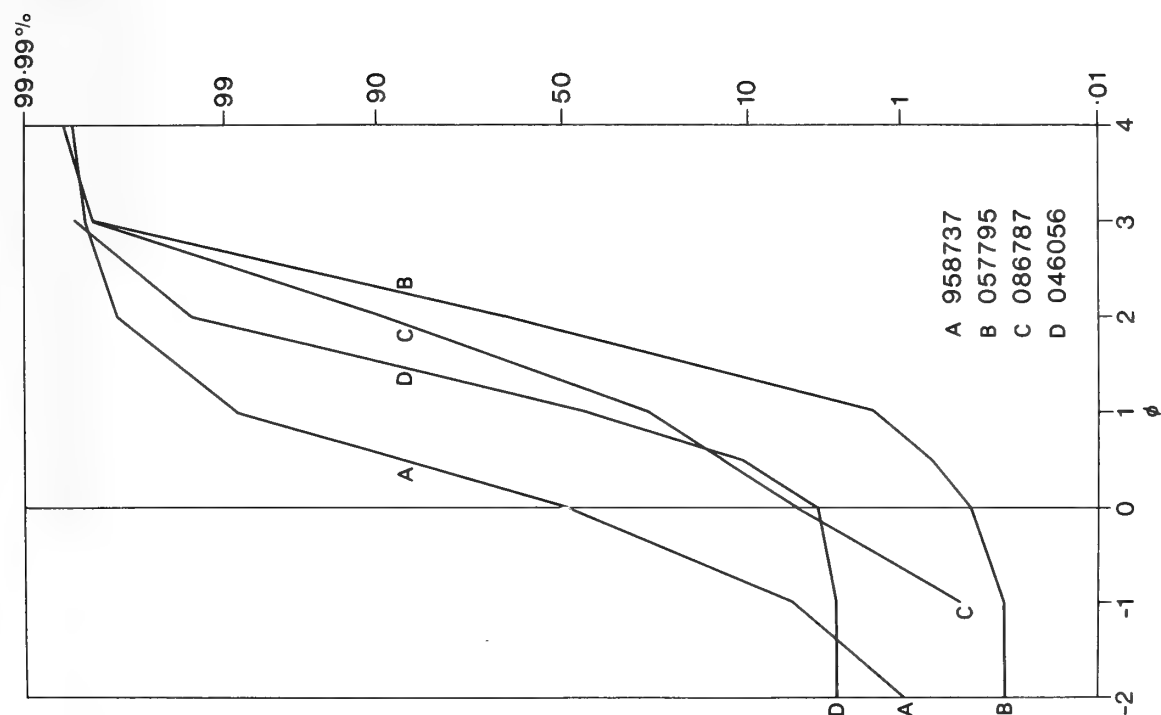


Figure 8. Size composition of beach sediments



Plate 2. Sparrowhawk Hill from the north coast beach ridge



Plate 3. Limestone ridge inland of the coastal salt pond at Charles Bight



Plate 4. Limestone ridge and coastal sand flat and salt pond at Mary's Bay

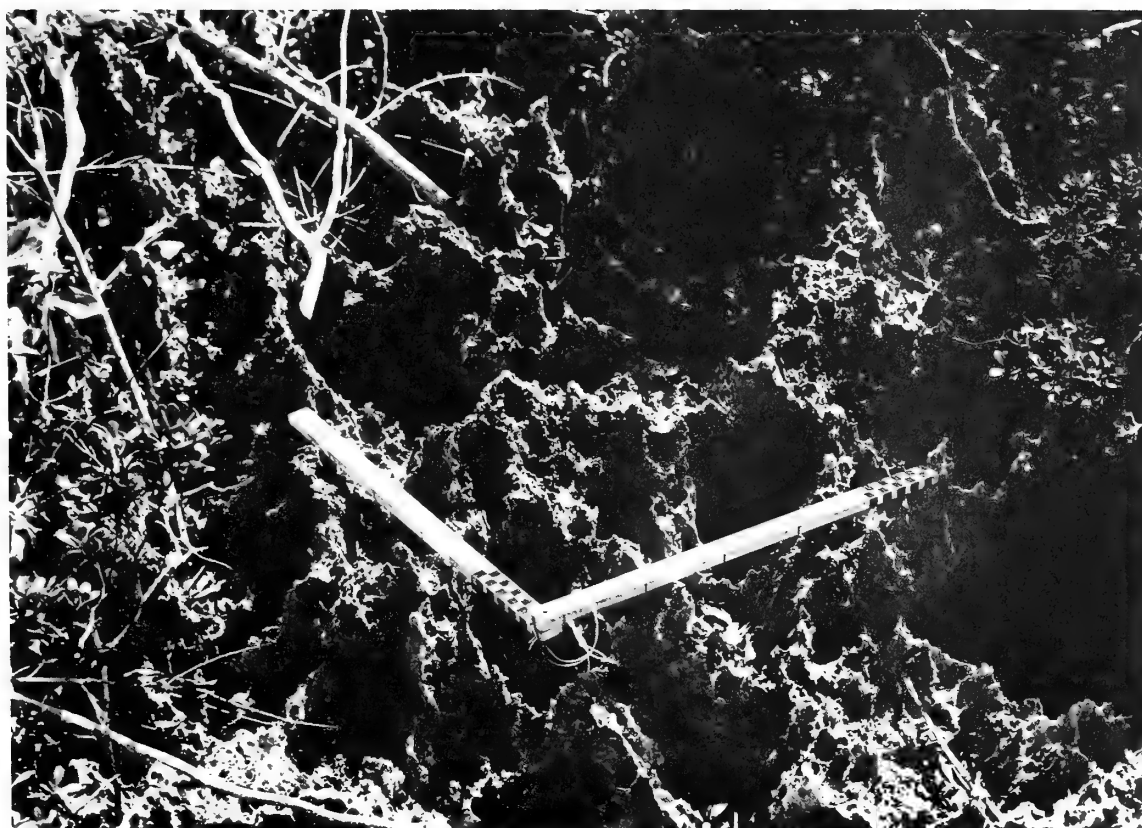


Plate 5. Dissected surface on the Bluff Limestone (6032 1783); the sides of the frame are 50 cm long



Plate 6. Detail of surface dissection on Bluff Limestone



Plate 7. Large doline in Bluff Limestone (6028 1778)

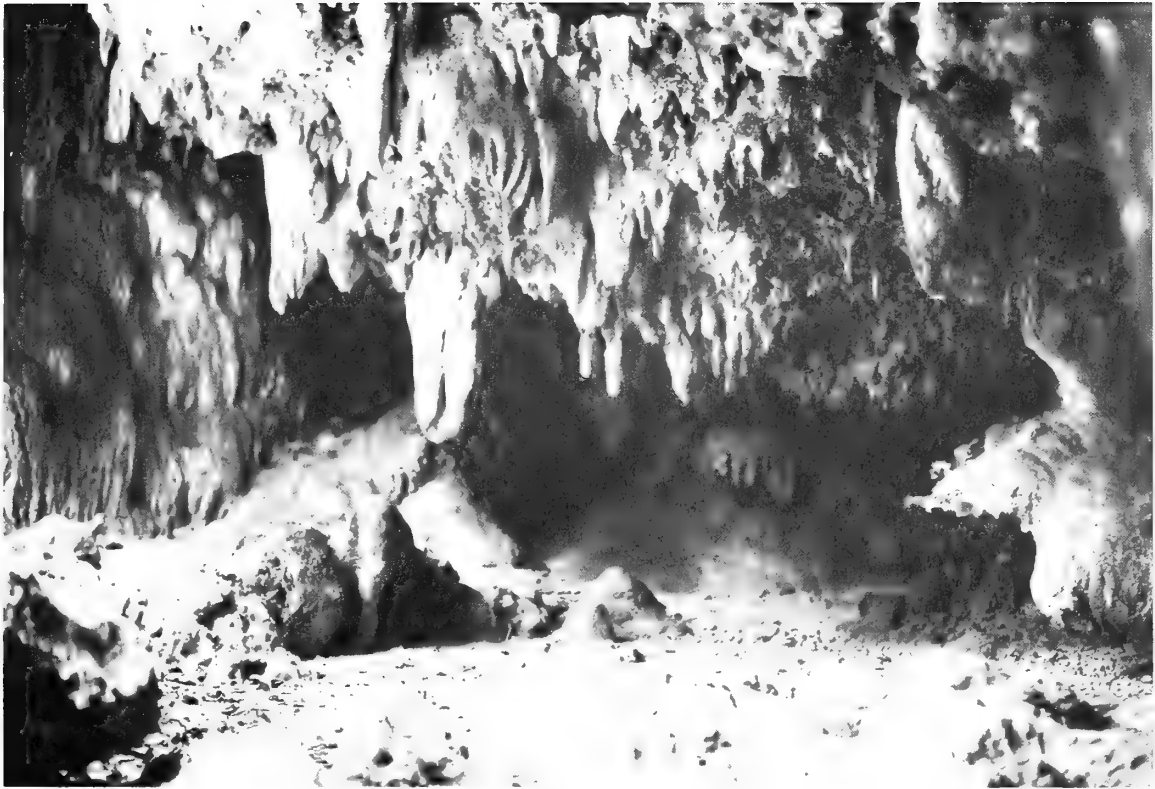


Plate 8. Cave speleothems revealed by roof collapse (6003 1781)



Plate 9. Bluff coast at East Point



Plate 10. Ironshore platform west of Calabash Spot



Plate 11. *Diploria* colonies in coastal Ironshire at Salt Rocks

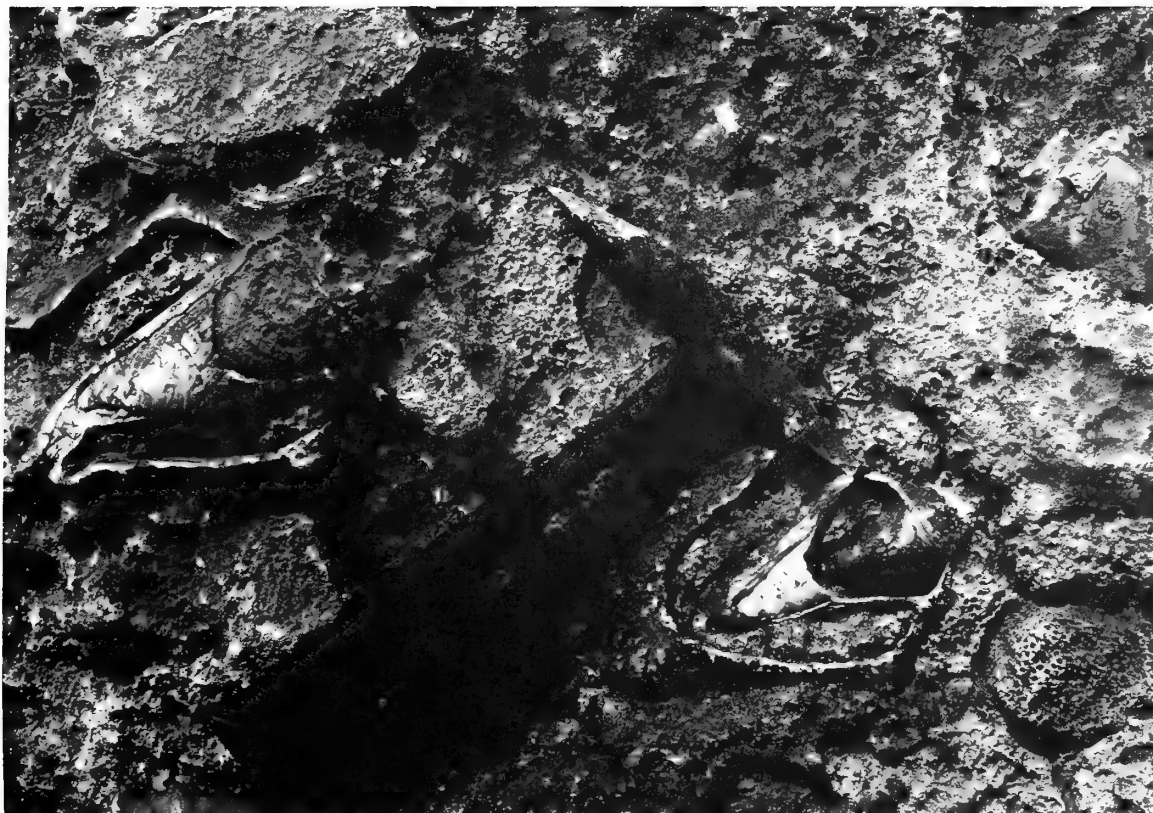


Plate 12. *Strombus* shells in coastal Ironshore at Salt Rocks



Plate 13. Ironshore deposits on the landward margins of the Blossom Village lagoon



Plate 14. Potholes in the Ironshore surface at Salt Rocks

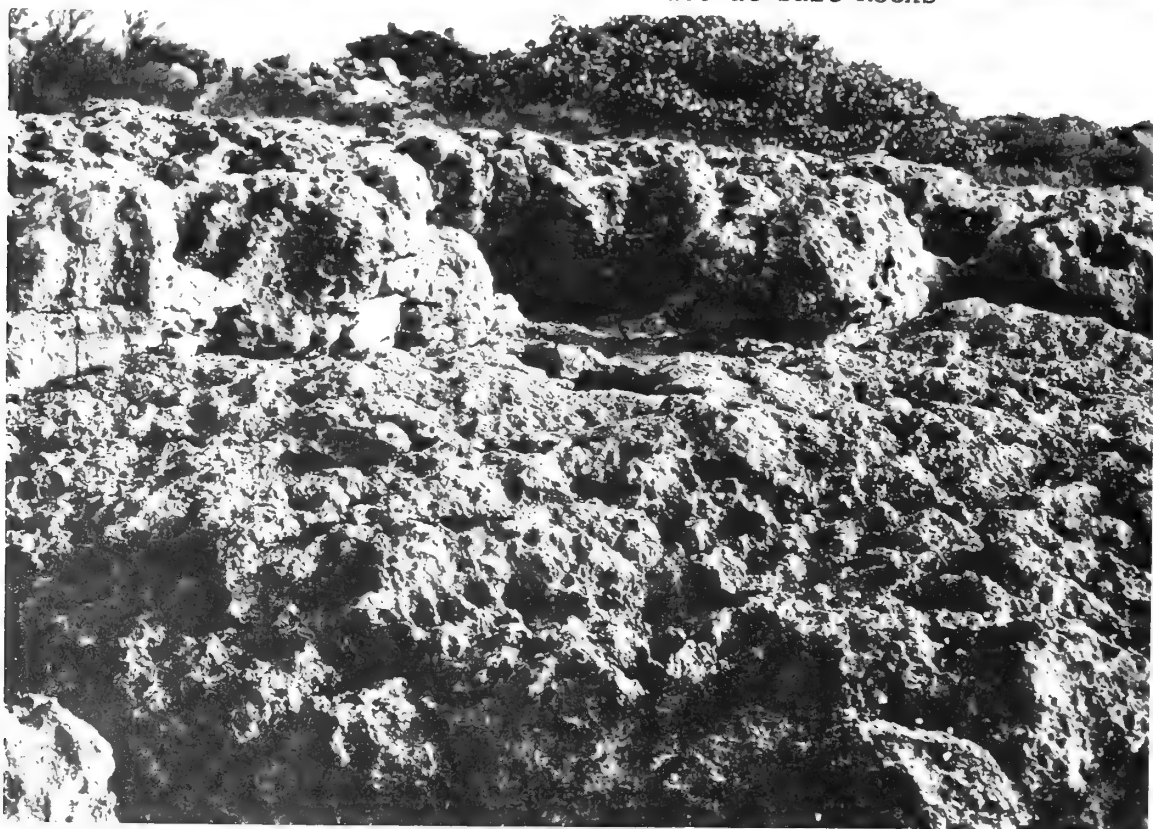


Plate 15. Bedded calcarenites overlying reef facies in the Ironshore at Salt Rocks



Plate 16. Detail of the bedded calcarenites at Salt Rocks



Plate 17. Beach ridge east of Pirate's Point



Plate 18. Beach ridge at Calabash Point



Plate 19. Sand beach ridge with juvenile *Casuarina* in Wearis Bay



Plate 20. Storm wash-over cobbles north of East Rocky Point,
Blossom Bay



Plate 21. Hurricane-deposited storm blocks on the Ironshore
platform south of the airstrip (5957 1737)

3. MANGROVE SEDIMENTS OF LITTLE CAYMAN

C. Woodroffe

The various mangrove habitats on Little Cayman are found on three different substrates:

- (i) bare rock substrates — which include the following habitats:-
 - 2A(b)* Low *Rhizophora* woodland on salt-pond margins.
 - 2A(c) *Conocarpus* and herbaceous vegetation of rock flats round salt-ponds.
 - 2B(b) *Conocarpus-Laguncularia* scrub of low dissected interior Bluff Limestone.
- (ii) sandy, silty and muddy substrates — as in the case of:-
 - 1C(a) *Rhizophora* and *Avicennia* coastal fringes, such as occur on the north coast of South Hole Sound, and on Owen's Island.
- (iii) Mangrove-derived peat substrates — Recent (Holocene) accumulations of organic sediments such as underlie:-
 - 2A(a) Tall *Rhizophora* woodland (Tarpon Lake).
 - 2A(b) Low *Rhizophora* woodland on salt-pond margins.
 - 2B(a) Dwarf inland *Rhizophora* scrub in enclosed basins.

The peat substrates are interesting because they contain a sedimentary record of the development of an area of mangroves, and changes in the environment of deposition can be detected in profiles through the peat.

*These codes refer to the habitat classification of Stoddart (this volume); see below, pp. 67-68.

The morphology of three areas, each part of a different mangrove habitat, were examined in detail. The depth to bedrock was probed, and the sediment was described from a series of cores through the peats, taken with a small hand-operated 'Davis'-type piston corer.

The three areas examined were:-

- (a) Dwarf inland *Rhizophora* scrub (habitat 2B(a)) at 976763.
- (b) Low *Rhizophora* woodland on salt-pond margins (habitat 2A(b)), where this occurred on a peat substrate, on the north coast, north of Sparrowhawk Hill, at 998783.
- (c) Tall *Rhizophora* woodland at Tarpon Lake, 005757 (The typesite and most extensive stand of habitat 2A(a)).

(a) Dwarf inland *Rhizophora* scrub

This inland basin of dwarf *Rhizophora* scrub (976763), oblong in shape, is colonised almost entirely monospecifically with *Rhizophora mangle*, all less than 2 m in elevation. At the edges of the basin isolated *Conocarpus* may be found, above the general level of the *Rhizophora* canopy, to heights of about 5 m. (the vegetation is represented schematically in Fig. 9).

A north-south transect was examined across the basin. A maximum depth of just over 2 m (205 cms) was recorded, occurring at the northern edge of the basin. This dwarf mangrove is not growing in a symmetrical basin; the basin is deeper at the northern and southern edges with a fairly consistent depth of just over 1 m in the centre. It must be remembered that this basin occurs on the dissected Bluff Limestone, with its characteristically karstic surface, and it is quite probable that this tortuous surface continues under the dwarf mangrove sediments, accounting for some of the variation of the probing in the centre of the basin.

Two kinds of sediments were recovered in cores under this dwarfed inland mangrove scrub:-

(i) Fibrous mangrove peat

Most of the Recent deposits within this basin are of fibrous, mangrove-derived peats. These are compact, well-structured, inelastic deposits, with a generally low moisture content. They are very dusky red in colour (2.5YR2/2 on the Munsell Soil Colour Chart); much of their red colour being due to the pink hue of the cortex of the root material derived from *Rhizophora*. The matrix of the peat is composed of narrow interwoven root fibres derived from *Rhizophora*, though larger root remains of the same species are not uncommon. These peats are homogeneous, and show little change with depth.

(ii) Shelly calcareous marl

Underlying the mangrove peat, but of limited extent, is a shelly marl or fine sand. This is white to off-white and crumbly when dry. The contact between the two sediments is fairly distinct, though root fibres from the peat are common within the marl and presumably penetrated down into the marl at a time when mangroves had colonised the surface. These fibres are intricately involved in the marl and have a covering of carbonate grains.

The carbonate grains composing the calcareous marl are angular to rounded; their surface is irregular under magnification, and it is evident that much of the material is skeletal in origin. The broken skeletal particles are presumably derived largely from the molluscan fauna of the sediment, and are therefore likely to be aragonitic. Some particles appear to be conglomerations of smaller particles though there is no extensive cementing of grains.

The fauna of this marl is dominated by the gastropod *Cerithidea costata* (Da Costa), which varies in length from juveniles of less than 5 mm to specimens of more than 21 mm. More numerous, though less conspicuous than this are the smaller gastropods, *Microdochus floridanus* Rehder. Also present are valves of an unidentified bivalve, probably a juvenile stage of one of the family *Cardiidae*. Another common element in the fauna is the ostracod of the genus *Cyprideis*.

This fauna is typically a fauna of brackish water or intertidal environments; indeed it is very similar indeed to the fauna at present found in Tarpon Lake (see later), and also found in other coastal ponds on Little Cayman. It seems likely that this inland mangrove basin was, at a time of lower sea-level, a brackish-water pool, probably with a fringe of *Rhizophora*. Subsequently the area of *Rhizophora* increased until the basin became entirely mangrove covered. Autochthonous ('in situ') accumulation of mangrove-derived peat continued until the surface reached its present elevation. The surface of the peat in these inland basins of dwarfed *Rhizophora* has been found to be close to present sea-level.

(b) Low *Rhizophora* woodland on salt-pond margins, on the north coast

A north-south transect was run across an area of low *Rhizophora* (4-6 m) which occurs fringing the salt-ponds on the Bluff Limestone plateau on the north coast, north of Sparrowhawk Hill (998783). The peat is generally shallow reaching a maximum depth of 65 cms. Small pools of standing water occur within the transect, and to the east and west are long narrow coastal lagoons, fringed again with *Rhizophora*. Odd trees of *Conocarpus* (6-8 m) occur at the southern end of the transect where the Bluff Limestone begins to rise in elevation. A narrow band of Bluff Limestone protrudes from the centre of the profile (Fig 10B).

The peat is very dark greyish brown (10YR3/2 on the Munsell Soil Colour Chart). Near the surface, it is fibrous and compact, composed largely of small root fibres of *Rhizophora*, with some larger root remains also included. At depth, the fibre content is less, the sediment is more plastic, less structured, and contains specimens of the intertidal gastropod, *Cerithidea costata* (Da Costa).

To the north of the profile there is a cobble ridge with a covering of *Coccoloba*, and boulders from this ridge lie on the surface of the mangrove peat.

The sequence of deposits, though only shallow, seems to suggest a progradation of *Rhizophora* into the coastal lagoon environment. The specimens of *Cerithidea* recovered in the basal peat are indicative of the lagoonal environment, while the fibrous peats are 'in situ' deposits of *Rhizophora*.

(c) Tall *Rhizophora* woodland, Tarpon Lake

A north-south transect was examined from the south shore of Tarpon Lake itself to the coastal beach ridge to the north of Wearis Bay (005757). This transect (Figure 10A) is through tall mangrove woodland, with *Laguncularia* (15-20 m) predominant, and with massive *Rhizophora* (25 m) at the lake shore. Small *Rhizophora* (4-5 m) occur on the inland flank of the beach ridge. The two predominant sediments in this profile are mangrove-derived peats, and pool sediments in Tarpon Lake itself.

(i) Mangrove-derived peats

The average depth of peat in this area is between 2 m and 2.6 m, apparently getting deeper towards Tarpon Lake. The peat varies in colour from dark brown, through dark reddish brown to very dark greyish brown (7.5YR3/2, 5YR3/2 and 10YR3/2 on the Munsell Soil Colour Chart); generally being greyer at the surface and becoming redder at depth. The peat is generally more moist than that encountered in inland areas of mangrove.

The peat is fibrous throughout, though generally less so at depth; the matrix being small root fibres of *Rhizophora*, larger root material occurring in places and several large pieces of greenish decomposing wood being recovered from depths of 80 and 100 cm.

Sand grains are found mixed with the peat in cores taken close to the beach ridge. These give the peat a distinctive granular texture. Sand grains may also be traced further away from the beach ridge, and are particularly evident at a depth of about 80 cms below the peat surface.

At the base of two cores examined to bedrock, but not at the base of a third, was found a 10 cm band of white to off-white sandy marl. This band of marl overlies bedrock, and has a fairly distinct interface with the overlying peat. It is granular and poorly consolidated.

The depth of peat overlying bedrock in the Tarpon Lake stand of mangrove (2.0 to 2.6 m) is very similar to the depth to a rock substrate in South Hole Sound, and it is evident that bedrock is generally continuous underneath the whole area. It is possible that the granular marl, of limited distribution at the base of the mangrove-derived peats, is a deposit very similar to the carbonate sands and muds in South Hole Sound.

The mangrove of Tarpon Lake is envisaged as developing on a bedrock floor very similar to the floor of South Hole Sound, and probably originating as marine mangrove of the type now found on the northern shore of South Hole Sound. It is not clear whether the beach ridge preceded the mangroves, with the mangroves filling in the space behind the beach ridge, or whether the mangroves preceded the beach ridge which was constructed outside a belt of truly marine mangrove. Of these two possibilities it is more probable that the mangroves preceded the beach ridge for three reasons. First, there does not seem to be any topographic reason why a beach ridge should be developed in the location that it is if there were not some barrier to its distribution further back onto the shoreline, such as a mangrove fringe. Second, mangrove-derived peat occurs, as substantiated in cores to bedrock within 50 metres of the beach ridge, throughout the profile to bedrock, and indeed pure peat underlies a mixed peat and sand at about 80 cms below the surface. Third, beach ridge sediments have been found to overlie mangrove derived peats on Grand Cayman.

(ii) Tarpon Lake sediments

The waters of Tarpon Lake are stained a foul reddish brown. The sediment flooring the lake, and usually only 10-15 cms below the water surface, and sometimes emerging from the water surface, are of the same colour. These sediments are largely a sand or coarse silt of carbonate grains, but with a relatively high organic content from the mangroves around the lake.

The carbonate grains are irregular in shape, and much of the material is evidently skeletal. The prominent mollusc is the gastropod, *Cerithidea costata* (Da Costa). Also present are the small gastropod, *Microdochus floridanus* Rehder, and valves of the unidentified bivalve, probably of the family *Cardiidae*, and in a juvenile stage. The other common component of the fauna of Tarpon Lake is an ostracod of the genus *Cyprideis*.

The depth of these sediments was not determined, but is probably in excess of 2 m.

Acknowledgements

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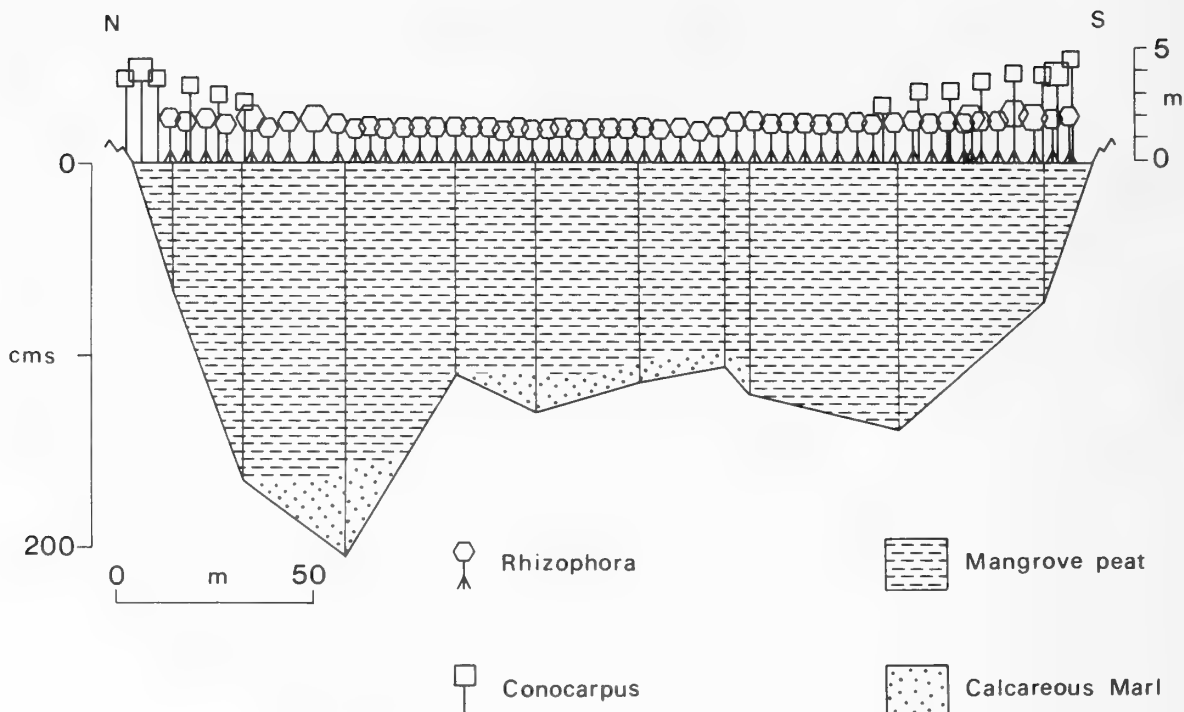


Figure 9. Topographic profile of inland dwarf *Rhizophora* scrub

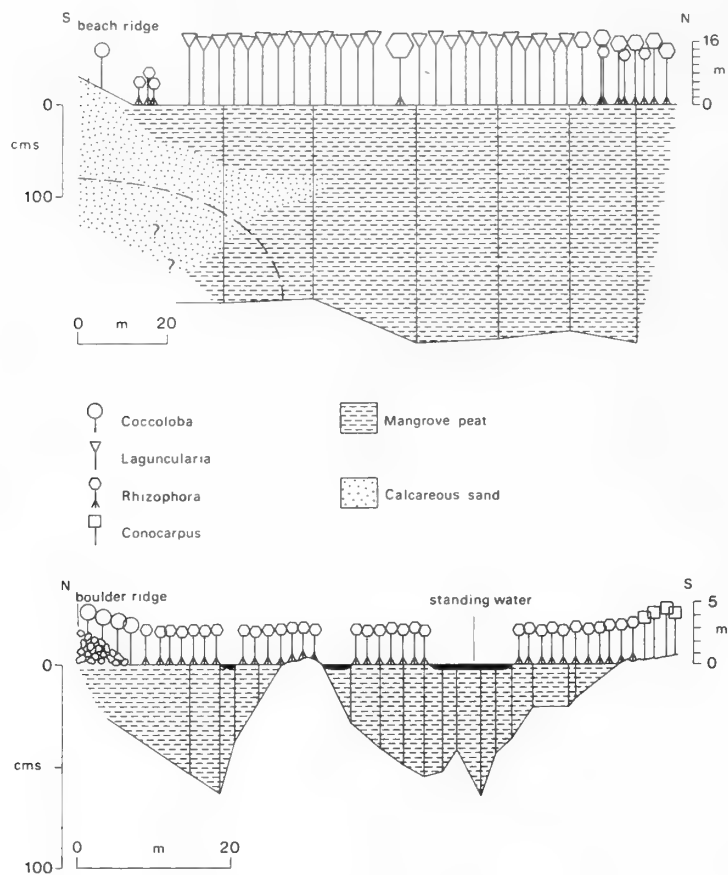


Figure 10. Topographic profiles of
A. *Rhizophora* woodland at Tarpon Lake,
B. North coast salt-pond *Rhizophora* woodland
near Sparrowhawk Hill

4. THE ZONATION OF ROCKY LITTORAL AREAS AROUND LITTLE CAYMAN

G.W. Potts

Abstract

The distribution of the rocky littoral fauna at sites representing different degrees of exposure were examined around Little Cayman. It was found that the molluscan species composition, species morphology and vertical distribution was affected by the exposure of a particular site.

Introduction

During July and August 1975 the Royal Society and Cayman Island Government supported an expedition to Little Cayman where aspects of the ecology of the island were studied. The Cayman Islands (between 19°15'N and 19°45'N latitude and 79°44' and 81°27'W longitude) are composed of three limestone islands which are formed by the projecting peaks of a range of submarine mountains that form the Cayman Ridge to the north west of Jamaica. According to Matley (1926) the central part of each island is comprised of an old "Bluff Limestone" while the periphery is made up of a mixture of coral sand, marl, and elevated limestone reef which has been weathered to form what is called the "Ironshore formation" (Doran 1954, Idyll, 1966). The limestone shore is extensively eroded by the action of rain, the sea, and also the grazing action of some littoral molluscs and the abrasive action of the shells or spines of some species of mollusc and echinoderm, as described by Ginsburg (1953) for the Florida Keys region. It was this rock that was examined in the present work on littoral zonation. The Cayman Islands are particularly interesting because they form a discrete island unit lying in deep water midway between Jamaica, Cuba and the northern coast of South America and yet there have been few studies specifically relating to the littoral region to these islands. Abbott (1958) provides the most important contribution to the marine molluscs of Grand Cayman and includes brief ecological notes in conjunction with a reasonably comprehensive species list. The zonation of littoral species on Little Cayman has not been studied before although it is to be

expected that in general terms it would be similar to that described for Grand Cayman (Abbott 1958) and for other areas of the Caribbean (Stephenson and Stephenson (1950, 1952), Coomans (1958), Voss and Voss (1955), Bakus (1968), Bakus (1975), and others). Nonetheless the survey did produce new records from a hitherto unstudied island with data on the influence of exposure on littoral rock faunas.

Methods

A number of areas were selected around Little Cayman to demonstrate the zonation of littoral animals (Figure 11). Each area was examined for species composition, distribution and abundance and then the profiles were drawn of the shore from the low water notch to above the strand line which occurred approximately one metre above the level of high water. Special attention was paid to the distribution of species in relation to their vertical zonation at sites on the leeward and windward shores. The influence of exposure and wave action were studied by selecting suitable boulders and assessing the distribution of molluscs on the seaward and landward faces of these rocks. Unfortunately time did not permit taking physical measurements of exposure which is here based upon the interpretation of such features as coral type, presence and extent of a storm beach, reef development, nature of particulate substrates as well as meteorological data.

No published tidal data was found for Little Cayman, however it is unlikely that it will differ significantly from the Admiralty Tide Table predictions for George Town, Grand Cayman (fig. 12) and this has been used as the basis for assessing the tidal levels.

Fig. 12 gives the fluctuations in tidal height throughout the period of the expedition together with the hour by hour changes in tidal height on a spring tide and on a neap tide. In areas with such a small tidal amplitude it is probable that local coastal morphology and meteorological conditions are more important in influencing the zonation of the fauna and flora than the tidal range (Gosline, 1965). The sites selected for examination represent a range of exposures from the extreme shelter of Owen Island within South Hole Sound to the exposed Bluff at East End, and several sites representing the intermediate exposure types. The sites examined were; in order from sheltered to more exposed sites; Owen Island within South Hole Sound, Jackson's Bay Rocks, Preston Bay, Rubble ridge that encloses South Hole Sound, West End Point rocks and the Bluff at East End.

While several groups of marine biota were represented in the littoral of Little Cayman the present survey deals in the main with the mollusca and decapod crustacea. Where possible provisional field identifications were made and samples taken for checking upon return. The following authorities have been consulted when identifying specific groups; molluscs, Warmke and Abbott (1961) Morris (1973); Neritidae, Russell (1941); the *Littorina ziczac* "complex", Borkowski and Borkowski (1969); hermit crabs, Provenzano (1959); stomatopods, Manning (1968); marine algae, Chapman (1963); and marine angiosperms, den Hartog (1970). The terminology used to describe the shore zones follows

Stephenson and Stephenson (1950).

Results

The results of the field surveys are outlined below, first describing the different survey sites, a comparative note on the size distribution of intertidal mollusca in relation to exposure. Finally the work is discussed in relation to other surveys from this region.

Preston Bay

Preston Bay (Plate 22) is on the South West side of Little Cayman and consists of a sand and coral rubble beach with occasional outcrops of eroded limestone. Beyond this littoral zone is the sublittoral upper reef terrace which varies between 200 and 400 m wide and which terminates on the seaward side with a coral buttress zone which itself is followed by a lower reef terrace. In addition to the limestone beach outcrop a small concrete jetty was examined.

Fig. 3 shows the profile of a representative rock outcrop from this region and also indicates the distribution pattern of the most important species. Above the beach rock is the supralittoral fringe comprising coral sand and coarse coral rubble. This mobile substrate was devoid of macrofaunal elements except in some areas of sand in which the burrowing crab, *Ocypode* sp. (probably *O. quadrata* (Fabricius)) was to be found. The only mollusc that occurred in this region was *Tectarius muricatus* on wood on the strand line and occasionally on coastal shrubs, such as *Suriana maritima* (L.), *Borrchia arborescens* (L.) DC. and others.

The rocks of the upper midlittoral zone contain species that depend upon periods of submergence for their survival. The most active is the crab, *Grapsus grapsus* (L.) which was common wherever rocks extend into this region. One specimen of *Goniopsis cruentata* (Latreille) was also found although it is more frequently associated with estuarine muds (Chace and Hobbs, 1969). The littoral gastropods *Echininus nodulosus*, *Nodilittorina tuberculata* (Plate 24) are tolerant of the more exposed conditions found on the dry surfaces of upward facing rocks, while *Littorina ziczac* and *L. lineata* are usually found in crevices, coming out and moving over the rock surfaces when the rocks are wet or at high tide. Where *L. ziczac* is found it may occur in large numbers and estimates of 1700 per square m were made where the substrate type and crevices provide suitable habitats. It was not possible to distinguish between *L. ziczac*, *L. lineolata* and *L. lineata* in the field so for these and subsequent population estimates they have been grouped together (see Borkowski and Borkowski 1969). Although samples from the different areas indicated which species were present. *E. nodulosus* was not as numerous and reached a maximum density of approximately 500 per square m. Both *L. ziczac* and *E. nodulosus* had patchy distributions and over most of the area their densities were much lower than those mentioned above. *Nodilittorina tuberculata* like *E. nodulosus* was distributed over the upper faces of the rocks and occupied much the same tidal level. It was interesting to note that

despite the similarity in habitat between these species, it was unusual to find these species together on the rock (see Abbott 1954 and comments on the distribution of these species).

The lower midlittoral zone is occupied in the main by nerites (Plate 26), but also contains faunistic elements of the upper midlittoral zone on rocks that drain and dry quickly, and infralittoral fringe species less tolerant of exposure to air. At Preston Bay *Nerita versicolor* occurred in the upper midlittoral zone and extended down to nearly low water mark. This species had the widest range of any of the littoral gastropods and was dominant in the upper levels of the lower midlittoral zone. The mid-tide level rock pools were occupied in the main by *Nerita tessellata* which over small areas was found in densities of over 200 per square m. On this particular beach *N. peroronta* was infrequent and a few only were found at about mid-tide level in rock pools or at the edges of them together with *Littorina meleagris*.

On the lower part of the midlittoral zone in both pools and on the open rocks was the chiton, *Acanthopleura granulata* which with *N. tessellata* were the dominant species at low water. The infralittoral fringe contained a wave cut notch that was subjected to strong wave action and which showed an increased species diversity. Here the first macroscopic algae were found and the intrusion of some members of the immediate sublittoral benthic communities. On the low water notch *Cittarium pica* and *Purpura patula* were found, the former reaching densities in excess of 40 per square m; but the convoluted nature of the shore made it impossible to do more than estimate at the population density. *P. patula* was less common. On the larger specimens of *C. pica* specimens of the limpet *Acmaea leucopleura* were frequently to be found at the edge of the body whirl adjacent to the columella. None of these sucker limpets were found on *C. pica* that was less than 4 cm in shell length although some were found free on the nearby rocks of the low water ridge. In the low level rock pools and along the infralittoral fringe specimens of *Echinometra lucunter* (L.) and less commonly *Diadema antillarum* (Philippi) were found, while in the sublittoral region *Echinometra* reached densities of approximately 50 per square m in the numerous crevices and fissures of the sublittoral rock.

A single specimen of each of *Tegula fasciata* and *Clathrodillia melanesiana* were found in the lower midlittoral zone. Beneath large stones in the lower midlittoral zone and in the infralittoral fringe the Tree oyster, *Isognomon radiatus* was not uncommon. Small specimens of the brittle star, *Ophiocoma echinata* (Lam.) were sometimes found beneath stones in littoral pools while larger specimens were found beneath stones over the upper reef terrace together with *O. pumila* (Lam.).

The rock pools and the immediate sublittoral rock contained most commonly the algae *Acetabularia crenulata* Lamx., *Padina sanctae-crucis* Børg. and an unidentified species of *Dictyota* sp., together with patches of *Turbinaria turbinata* Bart. which was also frequently washed ashore in wave swept areas.

The infralittoral fringe shows the beginning of the fauna of the upper reef terrace with corals tolerant of turbid conditions, *Siderastraea siderea* (Ellis & Sol.), *Millepora complanata* L. and others. Where the substrate is finely particulate the eel grass *Thalassia testudinum* König may come close to low water mark densely covering the area. *Syringodium filiformis* Kütz. was also found associated with *T. testudinum* in inshore areas.

Preston Bay Jetty

Within Preston Bay was a small concrete jetty 18 m long and 1.60 m wide. The alignment was approximately North South and its slope was 20 cm over its length ending 20 cm above LWMST at the southern end. The prevailing wind was from the South East and the water movement on the reef flat was from East to West so that the east side of the jetty was subjected to greater turbulence than the west side.

The distribution of gastropods reflected the difference in the exposure on the two sides of the jetty and clearly demonstrated that wave action and water movement will have a greater effect on the distribution of littoral species than the tidal amplitude. Fig. 14 indicates how the distribution varied along the jetty and from the exposed East side to the sheltered West side. This distribution is particularly striking as the jetty presented a relatively uniform substrate type without the numerous crevices of the surrounding rocks.

The species recorded from the jetty included *L. ziczac*, *N. versicolor*, *N. peloronta*, *N. tessellata*, *A. granulata*, *C. pica* (Plate 30) and *P. patula*. These gastropods were mainly living on the vertical walls of the jetty at each side. At high tide or when wave action was sufficient to cause the top of the jetty to be awash, the gastropods would move about over the horizontal surface. The crab, *Callinectes* sp. was seen below the tide level on the sides of the jetty while *Grapsus grapsus* was found in the upper midlittoral region.

West End Rocks

West End Point (Plate 23) consisted of a rock plateau below a sandy beach. The rock was several hundred metres in extent and contained several large rock pools which were examined. A profile of the rock is given in fig. 15 together with the distribution of the most common littoral species. To the South and East of the area a steeply sloping shingle and coral rubble beach exists and which joins a series of longitudinal limestone outcrops which slope to the seawards and which project from the shallow sublittoral of the upper reef terrace to a height approximately equal to HTL. These ledges join the rubble beach and extend Eastwards to join Preston Bay and the Preston Bay Inshore formations described above. To the North of West End Point rocks the particulate beach continued to join up with the extensive limestone shore at Salt Rocks.

At Preston Bay the beach is protected from the full wave energy by the buttress zone of the upper fore-reef terrace. At West End Point

there is no such protective barrier and the waves break directly on the rocks below the Tower light house. It is this wave action that replenishes rock pools in the midlittoral zone with seawater more frequently than would be expected by tidal movement alone.

The supralittoral fringe contained a strandline of wood debris with few marine species, and only *Tectarius muricatus* was found in abundance, although even this species was absent in areas of sand and where the drift wood rested on sand. The sand itself was highly mobile and yet contained a small population of *Ocypode* sp. The sand movement had scoured the upper midlittoral rock outcrops which were devoid of life, but below its influence *Tectarius muricatus* was found on the open rock and in dense numbers on the seawater tolerant *Sesuvium portulacastrum* L. (Plate 25). The littoral zone contained *Nodilittorina tuberculata* and *Echininus nodulosus* which were found on the exposed rock faces and in moist crevices together with *Littorina ziczac* and *L. lineata*.

The lower midlittoral species were more numerous than at Preston Bay and several species were abundant that were hardly represented at this former site. Once more the nerites, *N. peloronta*, *N. versicolor* and *N. tessellata* were common (Plate 26) and in particular *N. tessellata* which favours the rock pool habitat. In addition to these, the zebra nerite (*Puperita pupa*) and *Littorina mespillum* were found in large numbers in rock-pools (see Plates 34 and 35).

The lower midlittoral zone was more dissected than at Preston Bay Rocks and contained a greater density of molluscs. *N. tessellata* extends down to the low water notch where *C. pica*, *A. granulata* become the dominant molluscs. In the low water pools occasional *Echinometra lucunter* and *Diadema antillarum* were found. The low water concentrations of *Echinometra* increased in the sublittoral and reached densities equivalent to the sublittoral region of Preston Bay (50/sq m). Owing to the turbulent conditions on West End Point it was not possible to examine the immediate sublittoral from the seaward, but inspection at extreme low water showed that the algae were similar to those at Preston Bay with *Acetabularia crenata*, *Padina sanctae-crucis*, *Dictyota* sp., and *Turbinaria turbinata* were common, growing sparsely in the low level rock pools.

In this region the extent of the distribution of molluscs is affected by the increased exposure of this site. The greater wave action not only increases the height to which certain midlittoral species will extend, but also has a profound influence upon the pool faunas. The mollusca *Planaxis nucleus*, *P. plineatus*, *Litiopa melanostoma* and *Tegula excavata* were only found at this site at low tide level.

The hermit crab *Clibanarius tricolor* (Gibbes) was common and often very abundant in mid-tide level pools in the shells of *Echininus nodulosus*, *Nodilittorina tuberculata*, *Littorina ziczac* and *Cerithium variabile*.

Bloody Bay and Jackson's Point

In this region the upper shore consists of a poorly developed storm beach or coral boulders and rubble which rises to a height of 2 m above mid-tide level. Below this is a sand or sand and rubble beach that extends into the littoral region and in some areas onto the upper fore-reef terrace of the sublittoral region (Fig. 16). Occasional outcrops of rock provide the solid substrate essential for the development of a littoral zonation and two of these were examined.

The coastal fringe consisted mainly of sea grape (*Coccoloba uvifera* (L.) L.) except where an area had been cleared to provide the basis for a coconut plantation. In some suitable areas *Scaevola plumieri* (L.) Vahl, *Suriana maritima* and *Sesuvium portulacastrum* L. extended down to high water mark and on these *Tectarius muricatus* were found in some members. This high level gastropod was also found up to 2 m above MTL upon the driftwood of the supralittoral fringe. The first truly littoral molluscs, *E. nodulosus*, *L. tuberculata*, *L. ziczac* and *L. lineata* were only present in small numbers on the rocks, but did occur on the tops of large boulders in the littoral region where they would be subjected to the periodic splash from waves. The lower midlittoral is more extensive than at West End Point or Preston Bay and *Nerita versicolor* and *Acanthopleura granulata* (Plate 33) were particularly abundant both reaching densities in excess of 40-50 per sq m. *N. tessellata* and *N. peloronta* were present in the permanent pools of the lower midlittoral zone and *Cittarium pica* was found along the infralittoral fringe under and among the stones and ledges of this zone. Jackson's Point was not subjected to heavy wave action despite the absence of rubble ridge. Fig. 16 shows a section of the shore at Jackson's Point and the distribution of the most common species.

At Jackson's Point the distribution of gastropods around a large boulder was examined to see if the aspect and orientation had an effect upon their distribution. Fig. 17 shows a profile of this boulder and the distribution of some species that were on it. It is seen that the upper midlittoral species *E. nodulosus* and *L. ziczac* are unaffected in their tidal level regardless of the aspect of the boulder. However, the zonation of the lower midlittoral species *A. granulata* and *C. pica* indicates a higher tidal distribution on the seaward side where they would be subjected to greater wave splash. By contrast the nerites occurred on the sheltered landward side of the rock with *N. tessallata* slightly higher than *N. versicolor* and *N. peloronta*. The infralittoral fringe contained the alga *Valonia* sp. and in rock crevices *Echinometra lucunter* was common around the boulder.

The Bluff — East End

The East End of Little Cayman (Plate 29) consists of the Bluff Limestone, a weathered and dissected rock outcrop in the littoral region and with a storm beach of coral rubble behind the ironshore. The site is very exposed to south east winds.

A diagram of the distribution of the common species is given in Fig. 18. While the densities of mollusca are very variable some maximum figures were recorded at different levels on the shore. In the supralittoral fringe on drift wood *Tectarius muricatus* was very common (Plate 32) reaching densities of between 144 and 152 per square m while on the rocks of the upper midlittoral zone densities of between 32 and 56 per square m were typical. *Nodilittorina tuberculata* reached densities of 60 per square m and in rock pools *L. mespillum* occurred at over 168 per square m. Nerites were present in the littoral zone, but in smaller concentrations than the more sheltered shores in the south and west of the Island. They tended to concentrate at the margins of rock pools of the midlittoral zone. *N. versicolor* was the most common and *N. tessellata* occupying the same region was less abundant. *N. peloronta* was more widely distributed although at lower densities. The other species commonly associated with rock pools was the small littorinid, *Littorina mespillum* which was usually evenly distributed over the pool. *Acanthopleura granulata* and *C. pica* were common at low water level occurring in densities of 24 and 36 per square m respectively while *Purpura patula* was only found at low water and on the low water notch at densities between 2 and 10 per square m.

With the increase in wave action at the east end of Little Cayman several species were present that were not recorded from more sheltered sites. The most abundant in the lower midlittoral region was the mussel *Brachidontes exustus* that was common in crevices of this region. Others recorded were *Isognomon alatus*, *Coralliophylla abbreviata* and an unidentified species of vermetid.

Rubble Ridge

On the south side of Little Cayman running almost the whole length of the island the fringing reef is separated from the seaward terraces by a ridge of coral rock and rubble (Plate 29). This ridge does not seem to be comparable to the algal ridges of Indo Pacific atolls, and comprises of boulders ranging from a few cms up to about a metre in diameter. The ridge was breached in several places forming channels from the sea into the shallow lagoon, South Hole Sound. Waves splashed over the ridge in many places and at high tide almost the entire zone was covered in sea water and subjected to considerable wave action. Small patches of the black and red mangrove grew on the inside edge of the rubble ridge. The molluscan zonation on the ridge was similar to the ironshore outcrops described above except that there was no equivalent to the supralittoral zone. The zonation was only found on the seaward side of the ridge and not on the lagoonal side where apparently the lack of water movement and the consequent silting prevented the development of a rocky shore molluscan fauna.

The lagoonal beach of the rubble ridge consisted of sand or fine mud generally with *Thalassia testudinum* growing in dense patches immediately below low water. This was replaced by silted coral rubble upon which a yellow algae film covered large areas and in which mangroves had begun to grow. The central part of the ridge contained the largest boulders and it was this region that contained the upper midlittoral

fauna with *Tectarius muricatus* and in crevices *Littorina ziczac* and *L. lineata*. At the same level, but in more shaded situations, *Echininus nodulosus* and *N. tuberculata* were found, while under stones and in the moist areas between the boulders *Nerita tessellata* and *N. versicolor* were common together with grapsid and porcellanid crabs. On the outer rubble beach on the seaward side of the ridge, nerites were still common but with the increase in water movement *Cittarium pica* and *Acanthopleura granulata* became more abundant until at low water mark and in low areas of the ridge where water streamed from the seaward side of the ridge to the lagoon these two species became the dominant molluscs. *Cittarium pica* on the rubble ridge was covered in calcareous algae while those associated with the Preston Bay jetty were relatively clean (Plates 30 & 31). It is interesting to note that despite extensive searches neither *Nerita peloronta* nor *Purpura patula* were found. Beneath stones at the lowest levels *Echinometra lucunter* and *Isognomon radiatus*, were found, the echinoid extending in greater densities into the sublittoral.

Owen Island

Owen Island lies within South Hole Sound and is sheltered from the open sea by the rubble ridge (see above). The Island was not extensively studied, but samples of the common mollusca were collected. The typical rocky shore mollusca were present, but representatives of the low water species, *Cittarium pica* and *Purpura patula* were absent as were the littoral pool species. In the black mangrove areas to the north of Owen Island *Littorina angulifera* was common and among the roots the crab *Callinectes marginatus* was frequently seen.

The remaining molusc *Cerithium literatum* recorded from Owen Island is one that is characteristic of the *Thalassia* beds that are plentiful around this Island.

Size distribution of littoral mollusca in relation to exposure

In Table 3 the mean sizes of the common littoral mollusca are given against the sites from which they were collected. The sites are arranged from the most sheltered at Owen Island to the most exposed on the Bluff end of the island at East End. While some of the sample sizes are inadequate to draw clear conclusions from, some general trends are present which indicate the relationship between exposure and molluscan distribution and morphology. In the first place the high level *Tectarius muricatus* does not have any significant size differences between the sheltered and exposed sites. Only on the Rubble Ridge of the South Hole Sand was a small record found from a single specimen. The site is generally too low for this species, never extending as high as the supralittoral fringe and the specimen found cannot be considered representative. *Littorina mespillum* was found at too few sites to give any indication of the effect of exposure on body size, but it would be expected to be slight in view of the fact the species is mostly restricted to pools. The same can be said of *Puperita pupa* which is also confined to rock pools and was only found at the rocks at West End.

Table 3. Size distribution of the Common littoral Mollusca around Little Cayman

	<i>Pectarius muricatus</i>	<i>Nodilittorina tuberculata</i>	<i>Echinus nodulosa</i>	<i>Littorina ziczac</i>	<i>L. lineata</i>	<i>L. lineolata</i>	<i>L. mespilum</i>	<i>Nerita versicolor</i>	<i>N. tessellata</i>	<i>N. peloronta</i>	<i>Puperita pupa</i>	<i>Cittarium pica</i>	<i>Purpura patula</i>	<i>Acanthopleura granulata</i>
Owen Island	16.8 (32)	11.4 (17)	11.1 (58)	16.1 (4)	7.8 (3)	10.2 (2)	-	21.8 (20)	23.0 (1)	23.7 (10)	-	-	-	-
Jackson Bay	16.3 (8)	7.4 (5)	-	11.1 (2)	7.6 (3)	-	-	10.7 (6)	10.0 (2)	13.5 (2)	-	21.0 (5)	-	93.5 (8)
Preston Bay	-	-	10.7 (6)	11.2 (13)	6.7 (20)	-	-	14.4 (14)	10.6 (13)	22.3 (12)	-	14.8 (135)	42.5 (4)	69.8 (4)
Rubble Ridge	8.0 (1)	6.6 (12)	10.1 (9)	11.8 (1)	6.7 (5)	-	-	16.0 (10)	13.8 (21)	12.0 (2)	-	13.8 (24)	-	-
West End	-	6.6 (57)	11.4 (20)	-	3.9 (5)	-	2.5 (29)	-	-	17.0 (3)	6.1 (65)	-	-	-
East End	17.2 (21)	5.6 (45)	-	7.7 (15)	4.6 (7)	5.3 (2)	2.4 (5)	10.6 (9)	7.2 (38)	13.7 (14)	-	20.8 (104)	29.0 (9)	59.7 (7)

The figures in the body of the table represent the mean size in (mm) of named molluscs. The sample size is given in brackets beneath each size. The absence of figures does not mean that a species did not occur at a site but that a sample was not collected and measured.

With the exception of *Echininus nodulosa* the littorinids showed a gradation in size with increasing exposure. Thus *Nodilittorina tuberculata*, *Littorina ziczac*, *L. lineata* and *L. lineolata* all showed a decrease in size on more exposed sites. The same general trend was shown with *Purpura patula* and *Acanthopleura granulata*. The nerites, *Nerita versicolor*, *N. tessellata* and *N. peloronta* did not show a clear relationship with the exposure of a site, but each of these species was very large at Owen Island, the most sheltered site. It can only be assumed that perhaps the sheltered nature of this site or some other factor than the direct influence of exposure was responsible for the large Owen Island specimens. *Cittarium pica* is most frequently found at the infralittoral notch and in two fairly extensive searches and collections at Preston Bay and East End showed that specimens were larger at the more exposed East End. *Cittarium* apparently favours turbulent conditions and constant water movement as is shown by its habitat preference and size distribution. What is surprising is the large mean size of those individuals on the Rubble Ridge of South Hole Sound which appears to result from the absence of very small individuals found at the other sites.

It is interesting to note that with the absence of brackish areas around the coast, the nerite *Nerita fulgurans* was absent. This was predicted by Russell (1941) who pointed out that with its preference for brackish estuarine and harbour conditions it was unlikely to be found on the smaller islands of the Caribbean.

Rock Pool Faunas

Despite a small tidal range there were several areas where permanent littoral rock pools existed and which had an interesting and varied fauna and flora. The environment that these pools offered must have been subjected to a wide range of temperatures and salinity and these factors are likely to be important in influencing the species found in these pools. Two areas containing rock pools were examined, one at West End rocks (Plate 23) and the other in Jackson's Bay and from both areas specimens of the gastropods were collected and their zonation noted.

The littoral rock pools fall into three main types; the high level, mid tide and low level pools, and each is characterised by the type of fauna and flora present. It is not possible to give precise limits upon the height above chart datum that each category may occur in, as this varies with the degree of exposure to which the shore is subjected, but in general the greater the exposure and wave action the higher will each pool type occur. High level pools were found in the supralittoral fringe and are filled only by spray from wave action or by rain, and are characterised by green and brown algal slimes and by the lack of an obvious macrofauna. These pools occur at the level of *Tectarius muricatus* which may be found on adjacent rocks, stranded wood and shrubs of the supralittoral fringe, but never in the pools. Occasionally the crab *Grapsus grapsus* retreated into the high level pools when disturbed, but mostly they remained without a macrofauna.

The pools of the midlittoral zone were subjected to changes of water with each tide and on the exposed western end rocks to occasional replenishment from wave action. These pools were characterised by a varied gastropod fauna and occasionally some contained very large numbers of the hermit crab *Clibanarius tricolor*. Young fish were common and the littoral goby *Bathygobius soporator* was present in all permanent rock pools. The pools in the lower midlittoral zone were subjected to constant wave action and the faunal elements may contain an occasional representative washed in during rough conditions from the infralittoral fringe and the sublittoral region. Occasional algae were found including *Acetabularia crenulata* which was noticeably more common in the low level pools which with *Dictyota* sp., *Turbinaria turbinata*, *Padina sanctae-crucis* and others were typical of the infralittoral fringe and upper reef terrace. Stomatopods of the genera *Gonadactylus* and *Pseudosquilla* were also frequently found in the crevices within the pools.

Discussion

The water eroded limestone of the littoral region provides an interesting and diverse habitat for marine molluscs around many tropical atolls and islands. Despite the often limited tidal range a distinct zonation is found from high to low water mark, and has been the subject of reviews by Stephenson and Stephenson (1950, 1952), Southward (1958) and Lewis (1960). These works together with more detailed surveys such as those by Voss and Voss (1955, 1960), Arnow, St Clair and Arnow (1963), Houbrock (1968) and others have described the distribution and vertical zonation of littoral animals in the Caribbean. Vermeij (1973) also considers the distribution of littoral molluscs in his attempt to relate their morphological differences with habitat preferences. However, as yet, little work has been done on the Cayman Islands littoral region apart from a small and non-representative collection of molluscs made during the Oxford Universities Expedition to the Cayman Islands in 1938 (Salisbury, 1953) and the important work of Abbott (1958) who described the marine molluscan fauna of Grand Cayman. No specific records exist for Little Cayman.

While the present work does not represent a comprehensive species list of the kind offered by Abbott (1958), it does indicate the distribution and zonation of the common littoral species on the beach rock around Little Cayman in relation to the degree of exposure.

The way in which the degree of exposure influences the vertical distribution of species depends upon a number of factors, including the behavioural homeostatic mechanisms employed by the animal as well as their physiological tolerances (Lewis 1963, Fraenkel 1968, Hardin 1968, and Borkowski 1971). These factors together with morphological adaptations (North 1954) enable species to colonise and exploit widely different areas although it should be recognised that different species will often employ different mechanisms for maintaining themselves within their optimum range. In addition to the local variations in species distribution there are also zoogeographic variations of the kind described by Vermeij (1973). The present work confirms the general

similarity and local variability in species composition and zonation around Little Cayman with other areas within the Caribbean. (Stephenson and Stephenson 1950, 1952). The overall zonation includes a belt of maritime shrubs along the upper part of the shore. Where these extend down towards the supralittoral fringe *Tectarius muricatus* is found either on shrubs or wood on the strandline or on high level rocks. In this supralittoral fringe grapsid crabs may be present and on rocky substrates a range of upper midlittoral littorinids that extend to below mid tide level. In the upper midlittoral zone the first nerites are present generally near pools or moist crevices where there is little risk of desiccation. These extend to the infralittoral notch where the grazing *Acanthopleura granulata* and *Cittarium pica* become the most abundant species together with the carnivorous *Purpura patula*. In more exposed regions the lower midlittoral zone is characterised by vermitids and the mussel *Brachidontes*. The development of macroscopic marine algae is usually restricted to low level pools and it is only in the sublittoral region of the upper reef terrace that they become significant.

On Little Cayman it has been possible to show how around the shores of a single island it is possible to get a different species composition and zonation pattern that relates to the degree of exposure.

This has been recorded within the Mollusca and would probably be evident in other groups when subjected to detailed examination. Not only do different shores exhibit different species composition and zonation, but also within small areas of one shore it is possible to exhibit this effect. Thus on the seaward and shoreward side of a boulder, or the exposed or sheltered sides of a jetty, different zonation levels are exhibited. By measuring molluscs from different beaches it has also been possible to show that there is a difference of size between individuals found on shores of different exposure. In fact the individual species size ranges were often larger between different sites around the Island than Vermeij (1973) found for the same species taken from different areas of their zoogeographic range. Generally speaking there was a tendency for specimens to be smaller on more exposed shores, but this was not always clear and further work is needed to confirm this. Only with *Cittarium pica* was the reverse true.

The effect of exposure on a coastline is very variable, but with increased exposure there is generally more wave action which effectively increases the tidal range (Gosline, 1965). This enables a species limited only by the need for a brief period of submersion to increase its vertical range, provided it has the necessary adaptation to tolerate the greater effect of desiccation at higher levels. This can to some extent be achieved by reducing body size, or by adopting a semi-cryptic mode of life as seen in most high tide littorinids or by developing a close textured shell that will resist water loss as found in *Tectarius muricatus*.

Table 4. Distribution of littoral Mollusca

SPECIES	Tidal level	Presence in rock pools					
			Owen Island	Jackson Bay	Preston Bay	Rubble Ridge	West End
Mytilidae	IML				*		*
Isognomidae	IML	*					
	IML	*					
	IML	*					
Acmaeidae	LML-ILF	*	*			*	*
	IML	*		*			*
	LML-ILF	*					
Trochidae	LML-ILF	*	(*)	*	*	*	(*)
	IML	*					*
	IML	*		*			
Neritidae	IML	*	*	*	*	*	*
	IML	*	*	*	*	*	(*)
	IML	*	*	*	*	*	(*)
	IML	*	*	*	(*)	*	(*)
	ILF	*					*
Littorinidae	ILF		*				
	IML	*			*		*
	IML	*					*
	UML		*	*	*	*	*
	UML		*	*	*	*	*
	UML		*	*			*
	UML		*	*	(*)	*	*
	UML		*	*	*	*	*
	UML		*	*	*	*	*
	SIF		*	*	(*)	*	(*)
Rissoidae	IML	*					
Vermetidae							

Tectarius muricatus occupies the highest position of the truly marine gastropods along the strandline and it is interesting to note that the mean size did not vary significantly at different sites around the island regardless of the degree of exposure. However what did change was the height above sea level which was highest on the eastern most exposed end of Little Cayman. Along this storm beach is an extensive strand line of washed up timber and it is on this timber that the densest numbers of *T. muricatus* were found at a height that could only have been wetted by the occasional spray from rough seas during storms. In this position not only must *T. muricatus* be tolerant to the desiccating effect of the sun and wind as has been shown by Rosewater (1963), but it must also be able to tolerate the osmotic stress when wetted during rain.

The difference in species composition at any one site can be explained in terms of physiological tolerance, but it is probable that other factors are involved. Paine (1966) discusses the possible influence of predatory species and how in an area where space is at a premium, such as the littoral zone, then a reduction of predators may also create a less diverse system. The situation cannot be easily summarised in a dynamic environment like the littoral region where at high water, benthic species may be subject to predation by a range of sublittoral species, such as fish, and at low water avian or mammalian predators may become significant.

In the present work the presence of carnivorous gastropods does not appear to have any obvious effect on the molluscan diversity, but it is possible a more extensive survey would be necessary to be certain.

While there is a useful literature on the littoral faunas of the Caribbean rather few actually mention the significance of rock pools in this region. North (1954) comments on the erosion of pools as a result of wave action, but adds little to the understanding of these important littoral habitats. Houbrick (1968) recognises their importance in the coastal zone of Costa Rica and shows how certain molluscs tend to prefer pools to other littoral areas and Abbott (1958) comments that in the upper ironshore of Grand Cayman, *Puperita pupa* and *Littorina mespillum* were most common in "splash pools". The West End rocks on Little Cayman contained similar "splash pools" where the hermit crab, *Clibanarius tricolor* became very abundant, as did the goby *Bathygobius soporator*. Around Little Cayman other molluscan species were found in rock pools including *Litiopa melanostoma*, *Tegula excavata*, *Echininus nodulosus*, *Nodilittorina tuberculata*, *Littorina ziczac*, *Acmaea antillarum* and the nerites, *Nerita versicolor*, *N. tessellata* and *N. peloronta*. In low water pools the echinoids *Echinometra lucunter* and *Diadema antillarum* were present; the former being recorded in pools of the inshore rocky areas of Florida Keys by McPherson (1969).

Apart from the molluscan collections by Salisbury (1953) and Abbott (1958) very little has been done to the littoral fauna of the Cayman Islands and nothing has been published specific to Little Cayman. The neglect of the littoral region is not justified as it offers a varied and diverse habitat in which many species live. Around the

island the differing degrees of exposure have an effect upon the species present, their morphology and upon their vertical range in the littoral zone.

Summary

(1) The littoral rocks of Little Cayman have been examined at different sites around the Island representing different degrees of exposure.

(2) A species list has been compiled and the size distribution of the common littoral molluscs indicates that despite local variability exposure has an effect upon the mean size for any one site. In general the greater the exposure of the site the smaller the shell size although in some species the reverse is true. Some species exhibit a greater size range around the atoll than is recorded in the zoo-geographical literature.

(3) The vertical zonation of molluscs is affected by the exposure, thus on a more exposed shore or part of a shore the vertical range is often extended.

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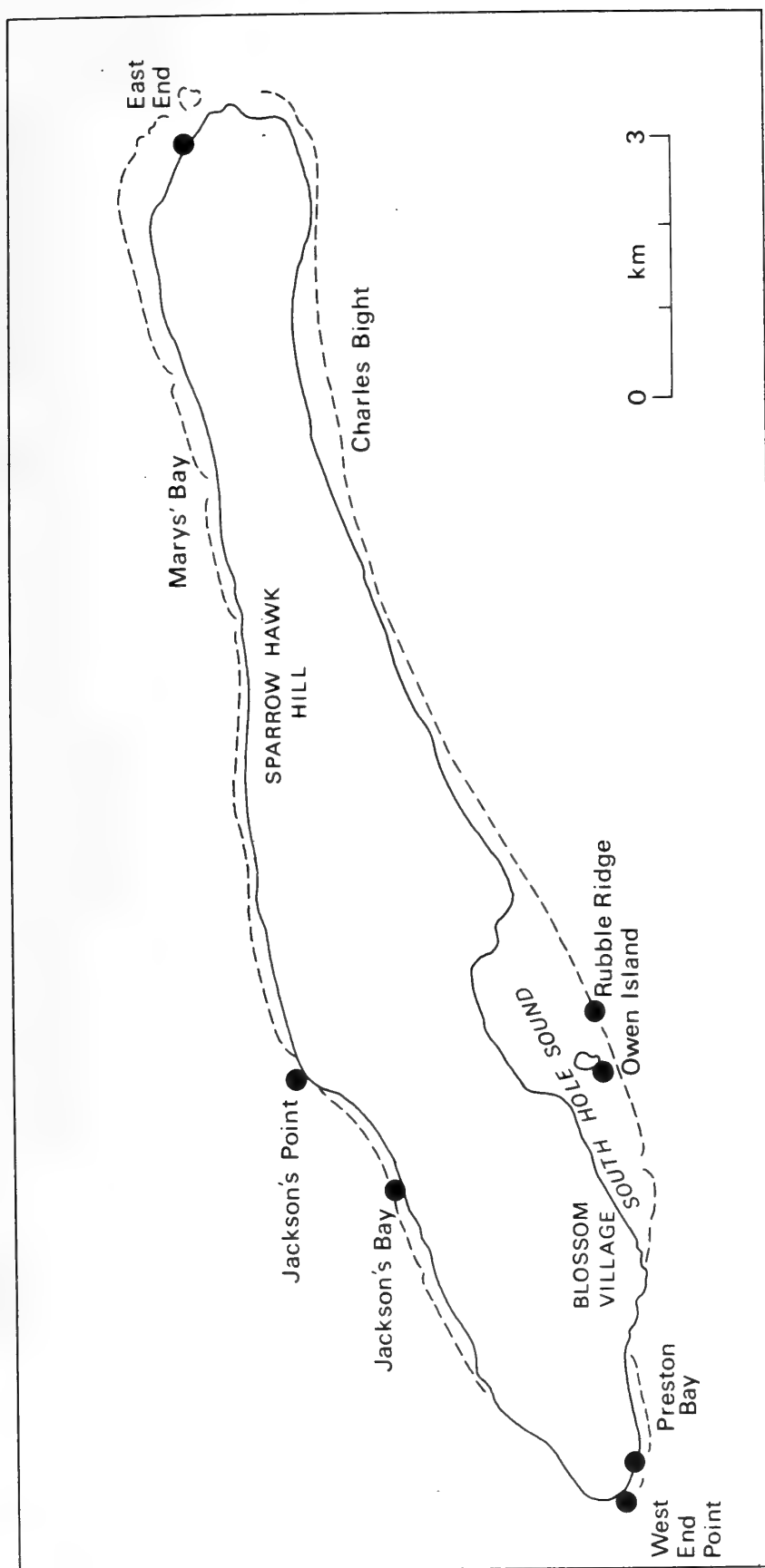


Figure 11. Map of Little Cayman showing the main coastal sampling areas

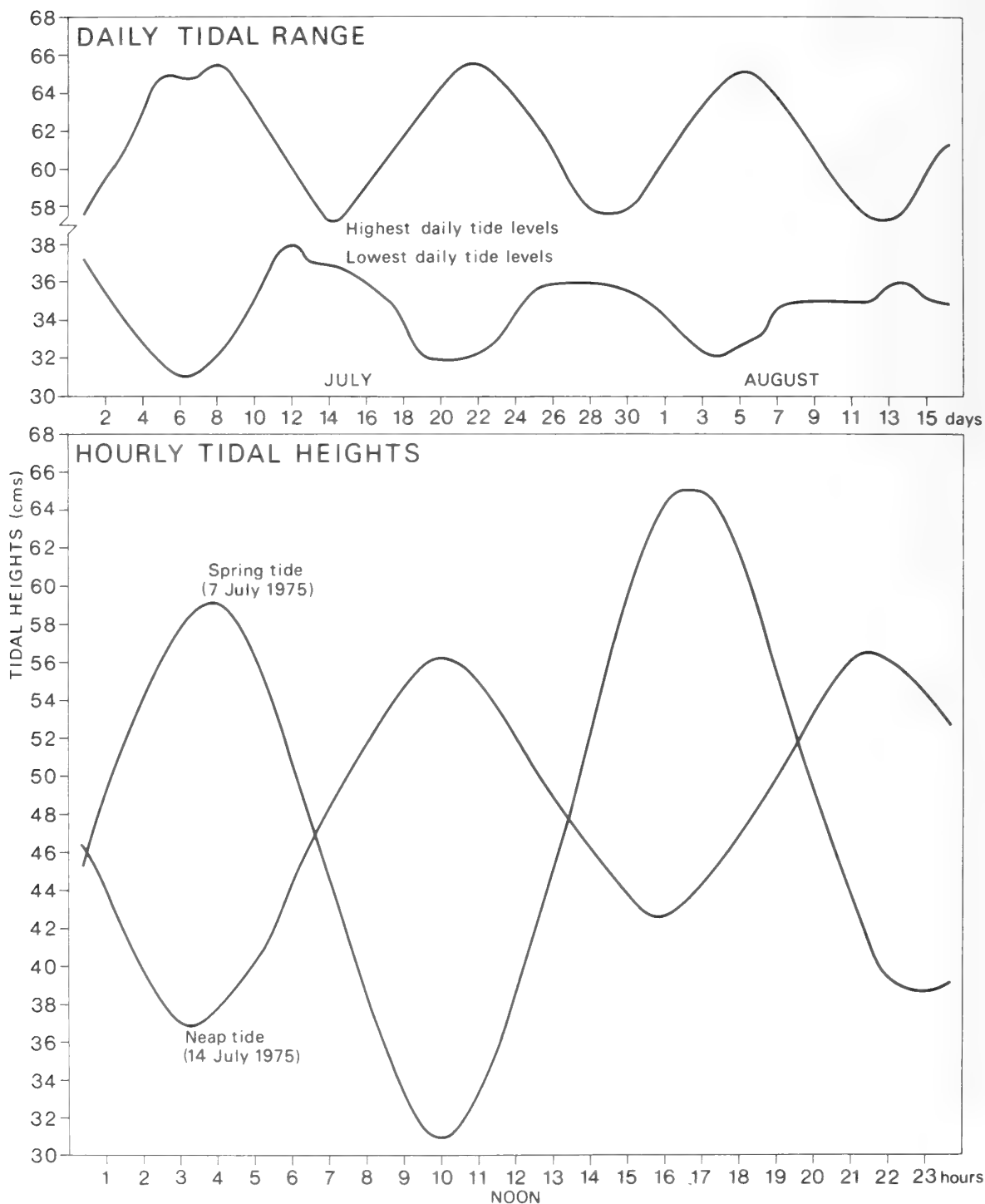


Figure 12. Graphs of the daily tidal range during the period of the expedition together with hourly tidal heights on a neap tide and a spring tide. The data were provided by Dr. K. George and based on figures obtained from *Admiralty Tide Tables*, Vol. II, 1975

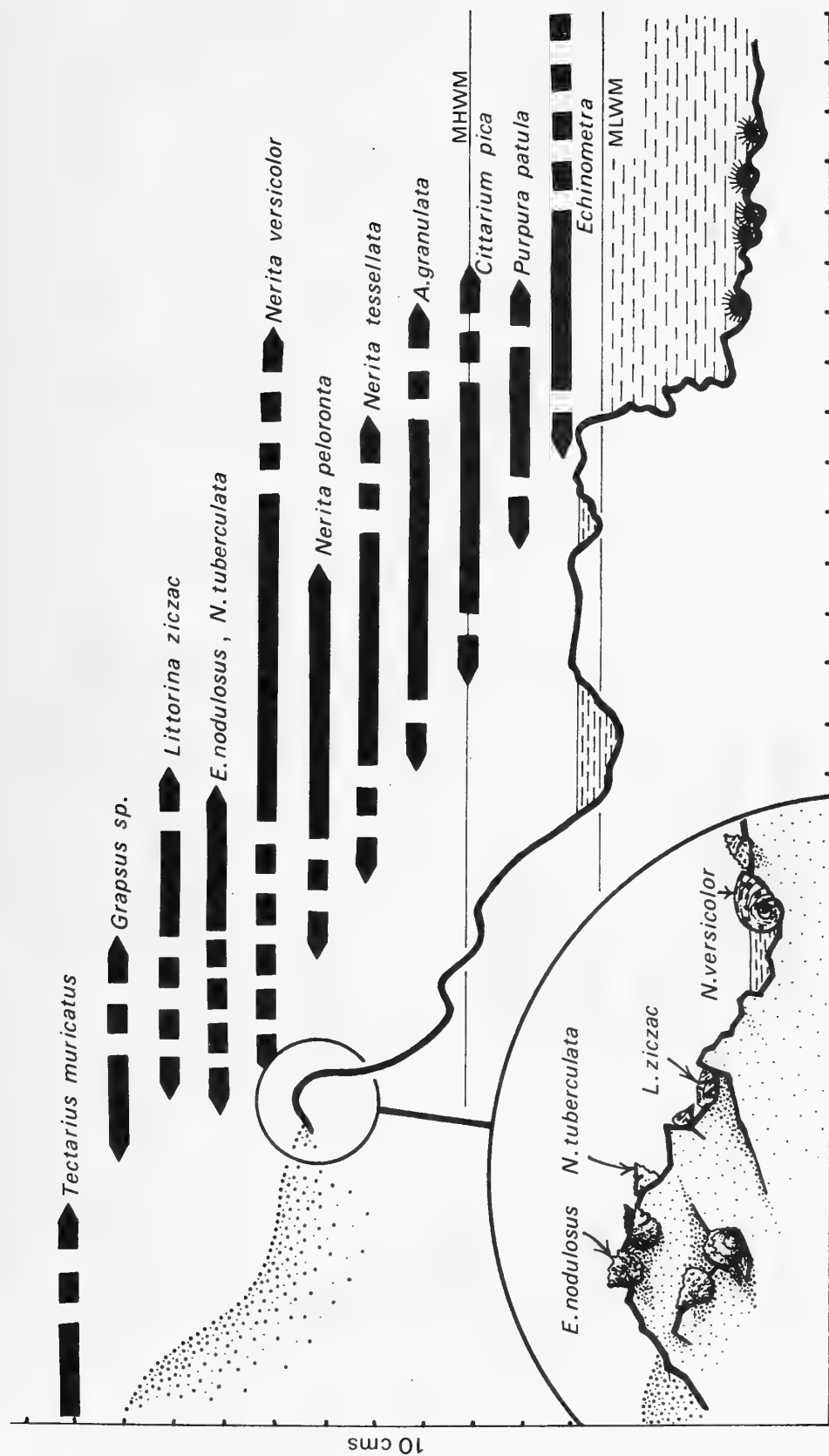


Figure 13. Profile of the shore at Preston Bay with an indication of the vertical zonation of the littoral species. The inset shows how on the upper shore some species remain in pools (*Nerita versicolor*), in moist crevices (*Littorina ziczac*), and on the open rock (*Echinus nodulosus* and *Nodilittorina tuberculata*), *Littorina ziczac* refers to the appropriate species of the *L. ziczac* "complex" (Borkowski and Borkowski, 1969) found in an area, and does so in subsequent figures

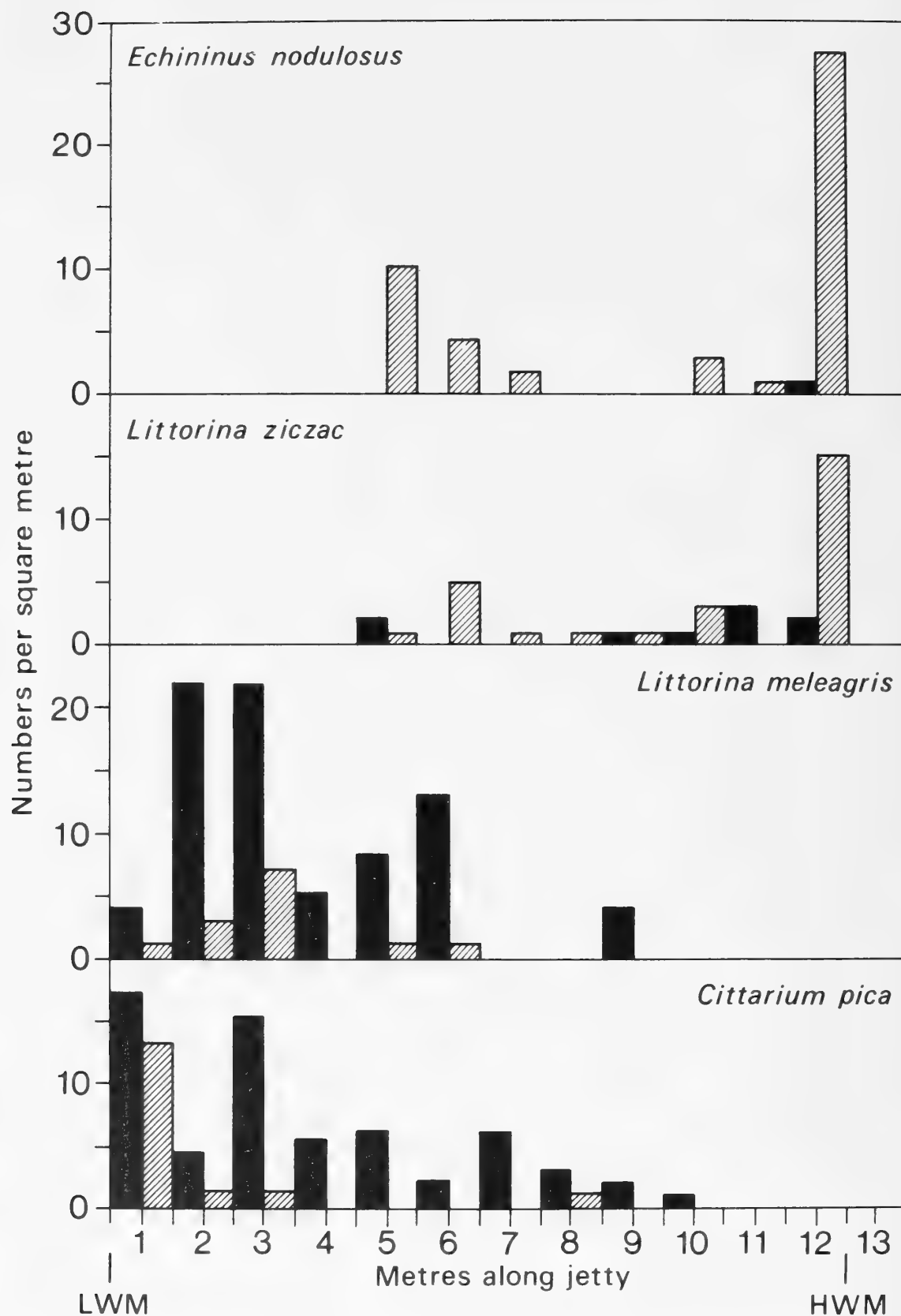


Figure 14. Histograms indicating the distribution of four species of gastropod along the jetty at Preston Bay. Black columns represent the east side of the jetty and stippled columns the west side

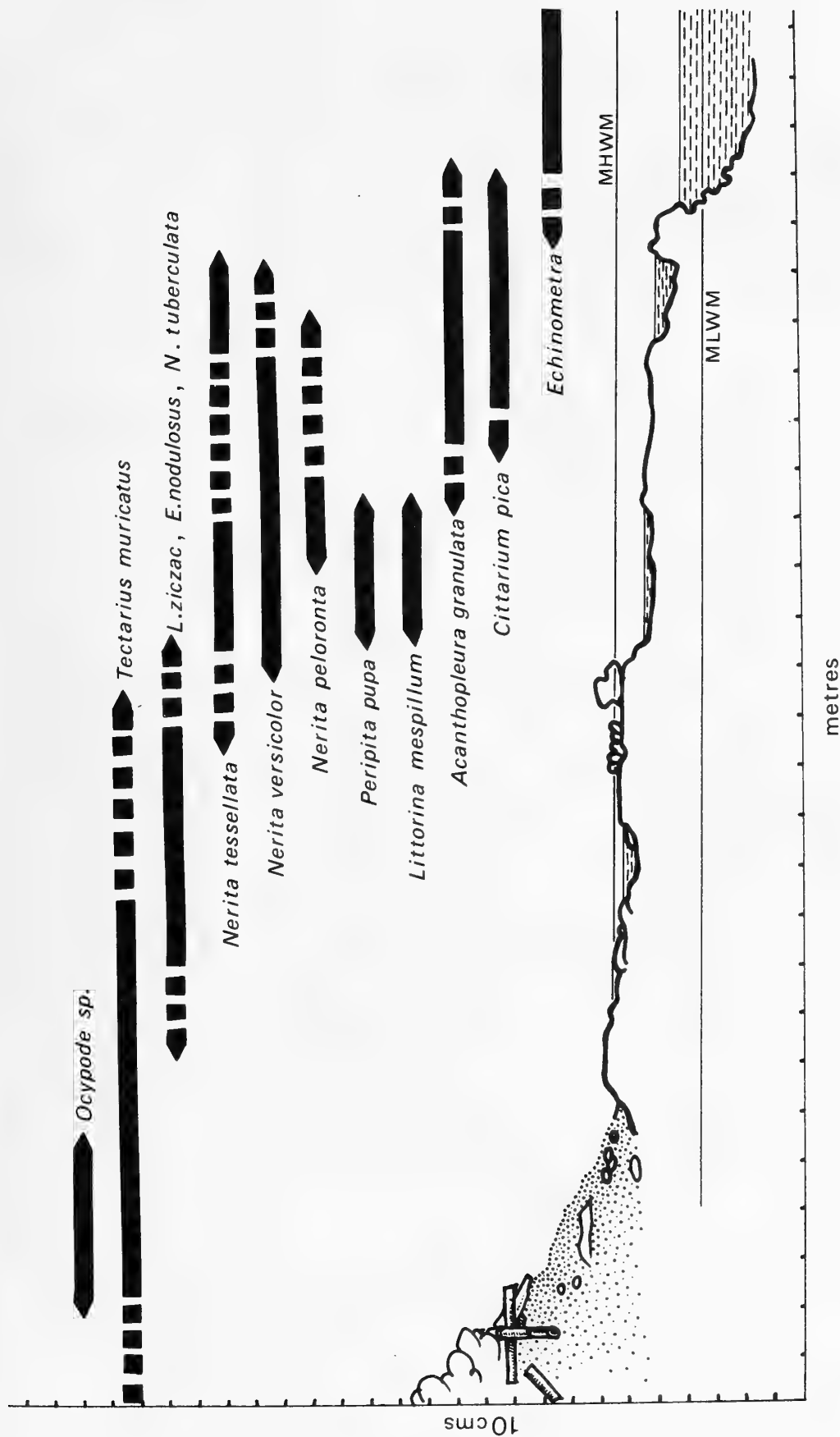


Figure 15. Profile of the shore at West End Rocks with an indication of the vertical zonation of the common littoral species

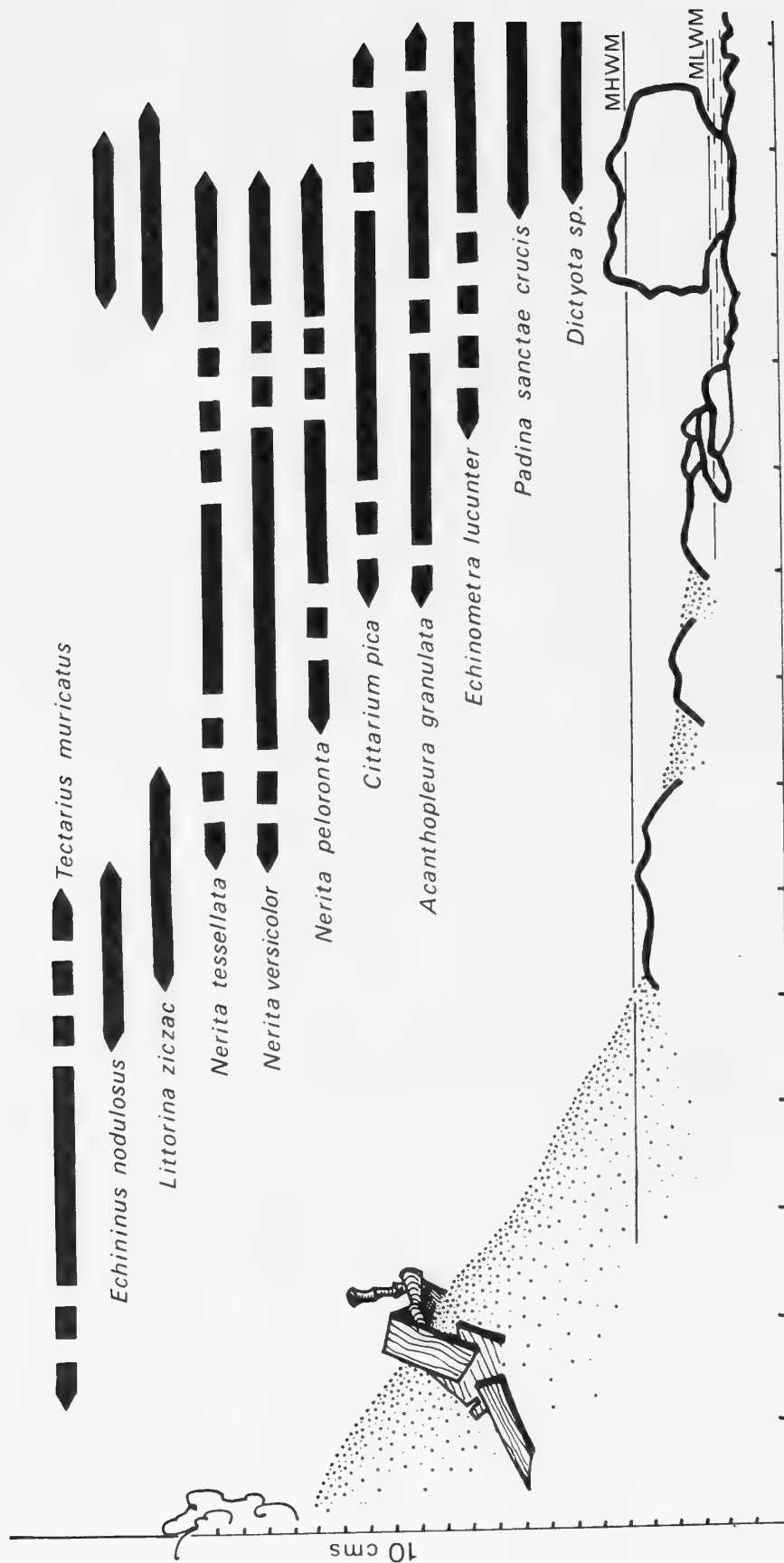


Figure 16. Profile of the shore at Jackson's Bay Point indicating the vertical zonation of the common littoral species. The double occurrence of some littorinids and nerites is a result of their presence on a large boulder found just below MLW.

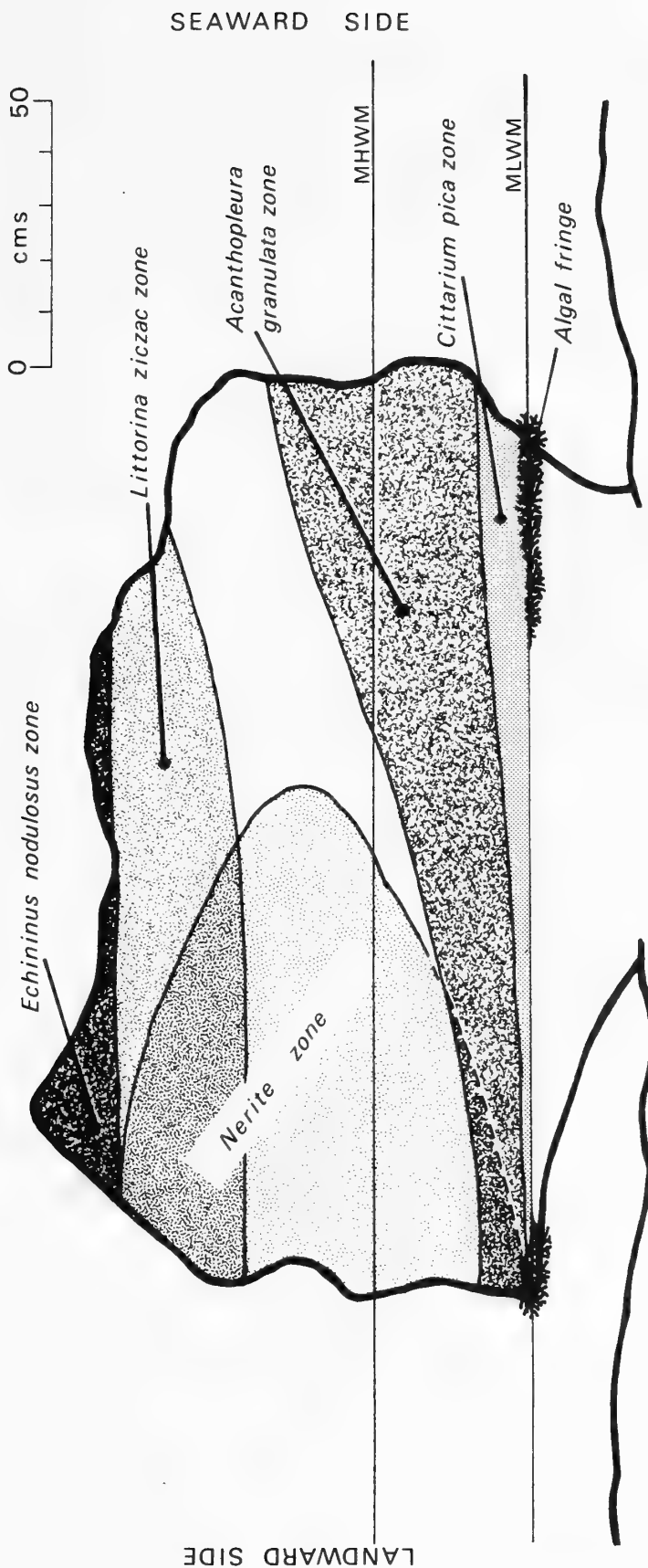


Figure 17. The distribution of molluscan zones around a boulder at Jackson's Bay Point (see Figure 16). It should be noticed that there is a difference in the extent of the zones on the seaward and landward sides of the boulder

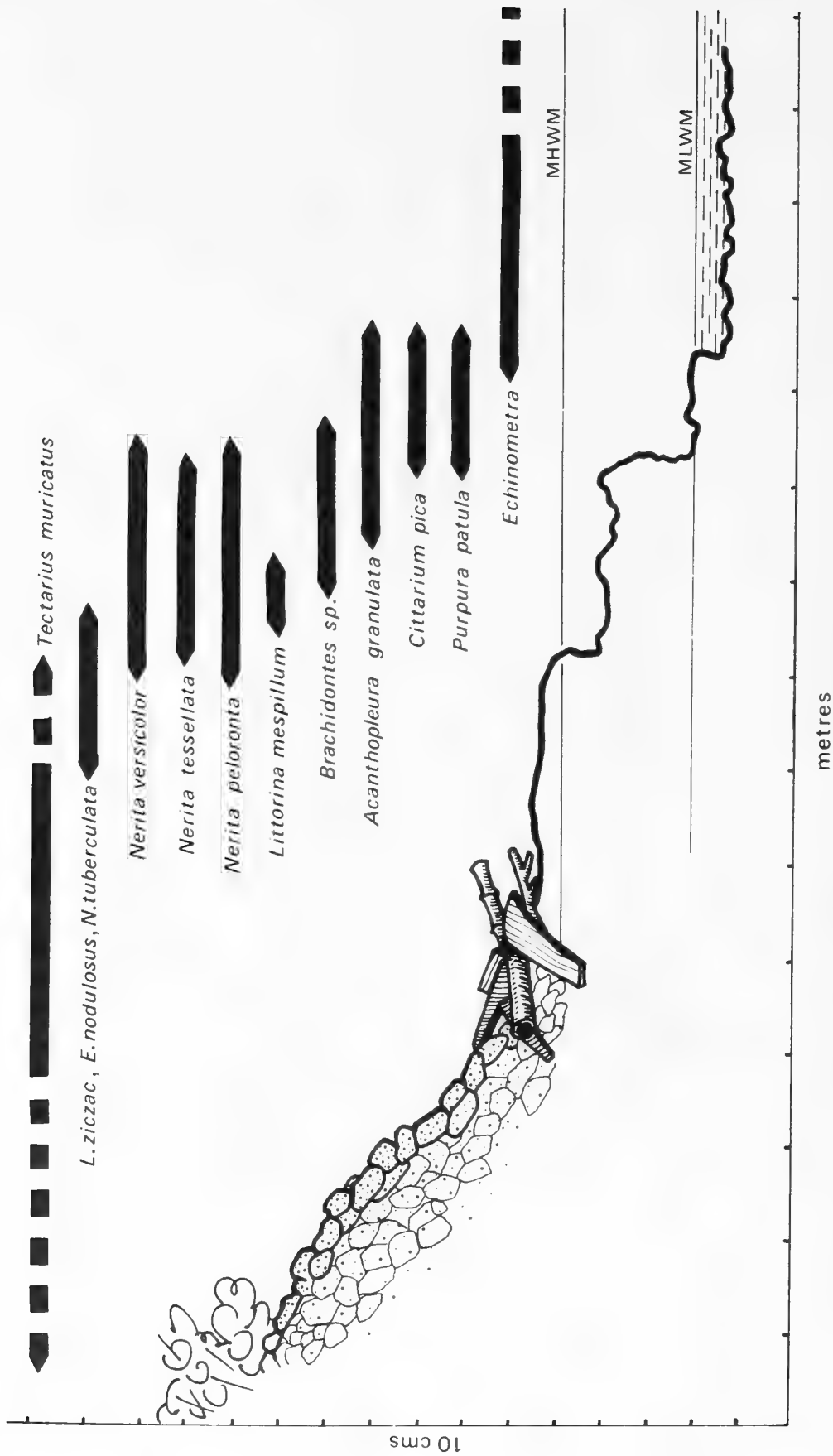
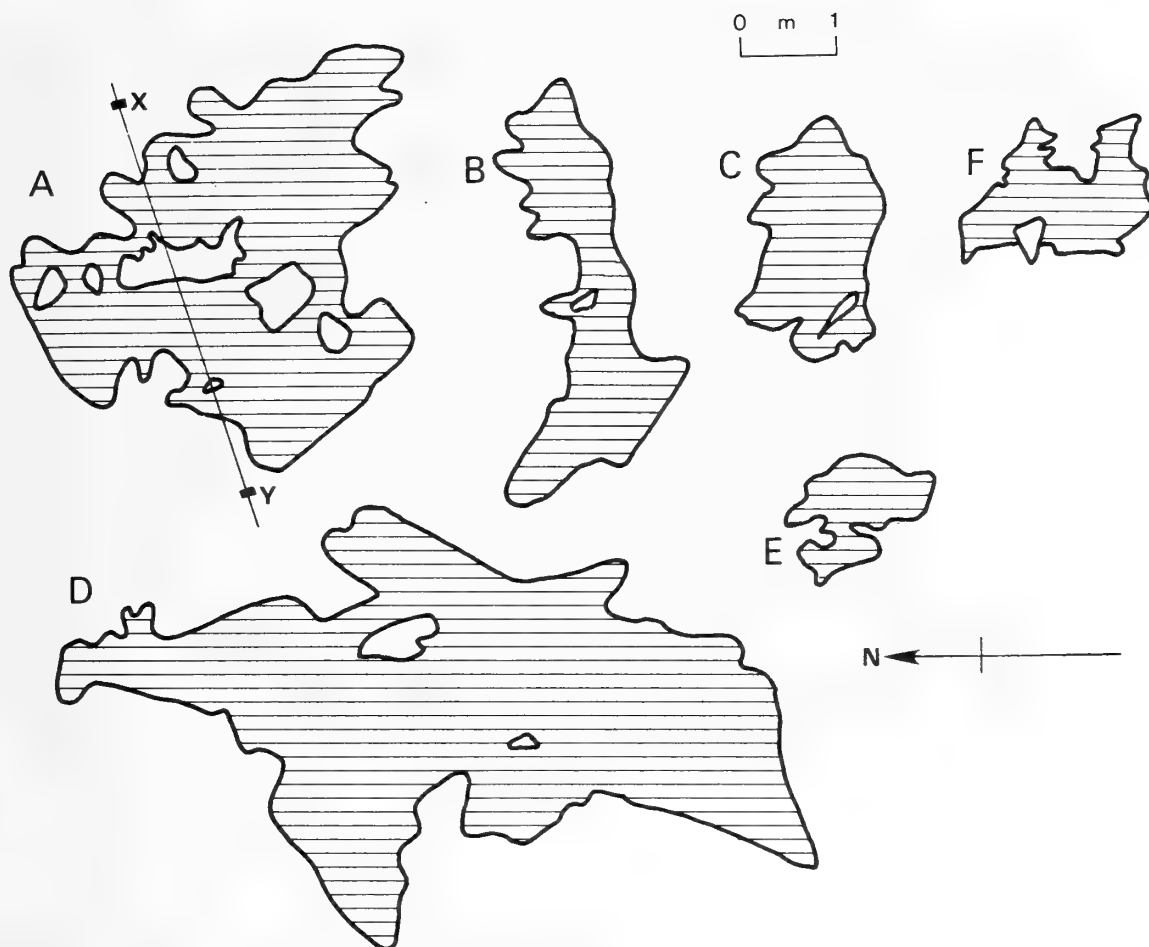


Figure 18. Profile of the shore at the East End indicating the distribution of the common littoral species



Section X - Y Pool A

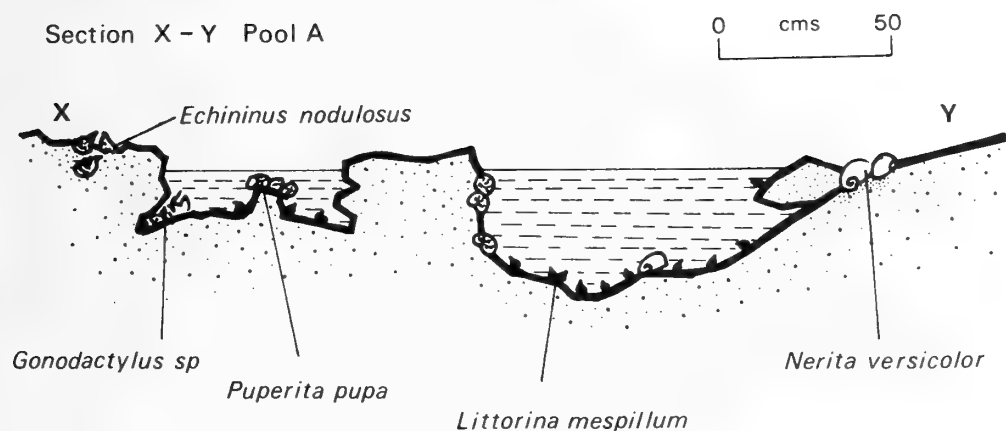


Figure 19. Outlines and orientations of littoral rock pools at West End Rocks and Jackson's Bay. Pools A, B and C occurred at approximately mid-tide levels and D, E and F at low tide levels. A diagrammatic section X-Y of pool A is given with the distribution of some of the common rock pool invertebrates



Plate 22. Preston Bay showing the exposed littoral rocks and sand beach above them



Plate 23. West End Rocks with a large littoral rock pool in the foreground

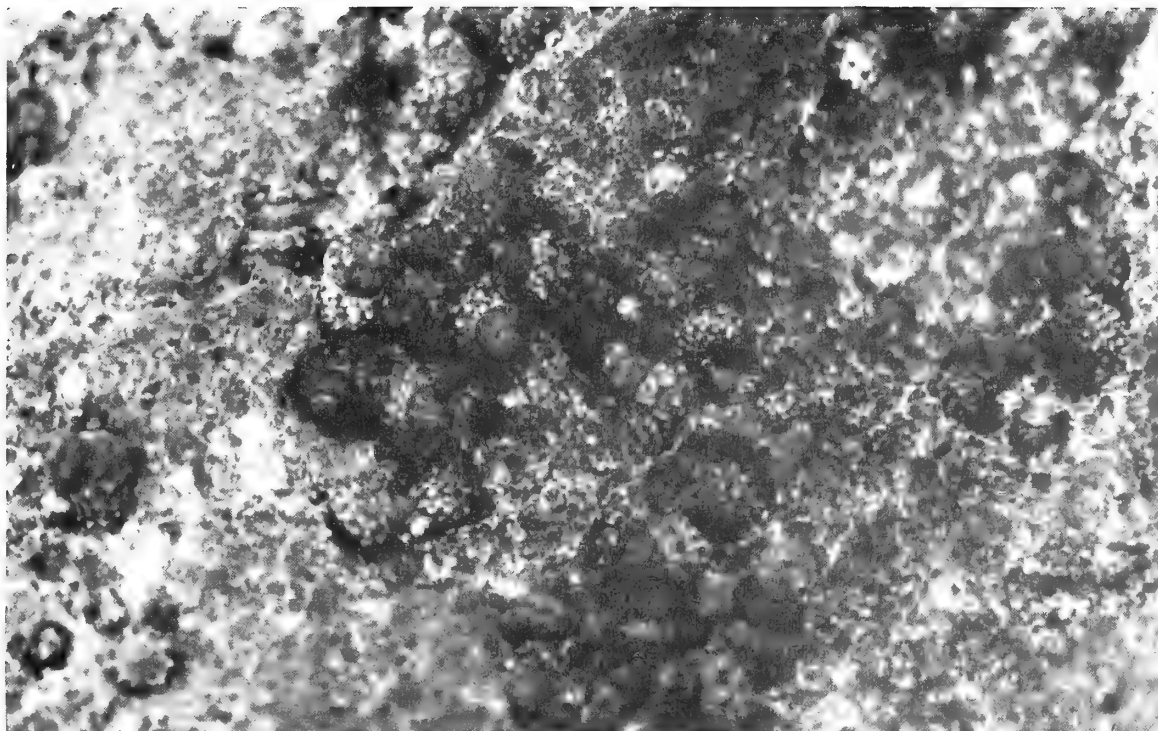


Plate 24. *Echininus modulosus* in crevices with *Littorina ziczac* on the upper midlittoral region of Preston Bay

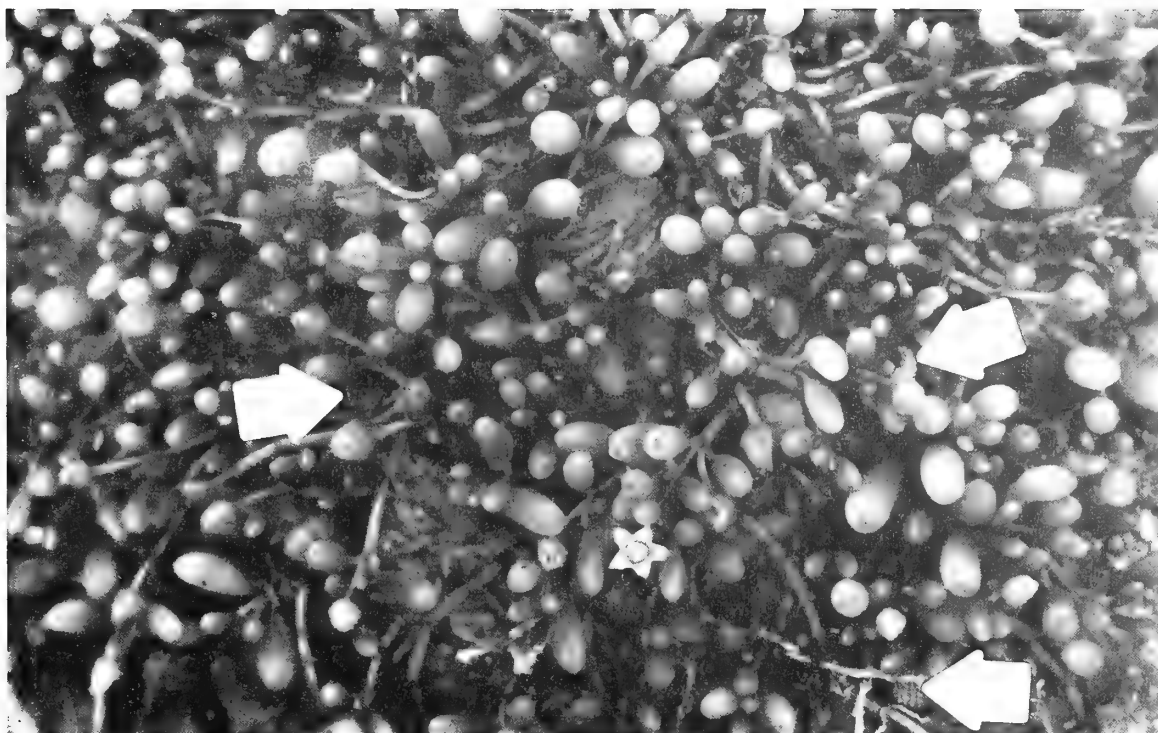


Plate 25. *Tectarius muricatus* (arrows) among the leaves of *Sesuvium portulacastrum* at West End Rocks

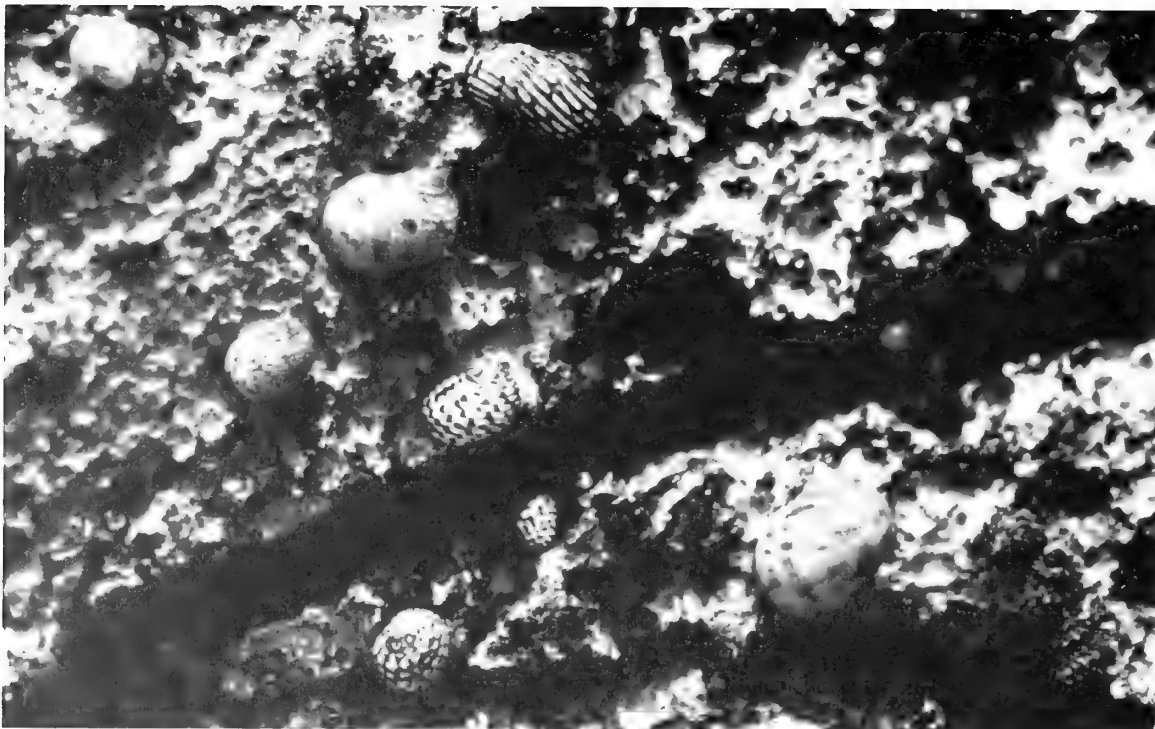


Plate 26. *Nerita peloronta* and *N. tessellata* on rocks at the midlittoral zone. *Echininus nodulosus* and *Littorina ziczac* are present in crevices

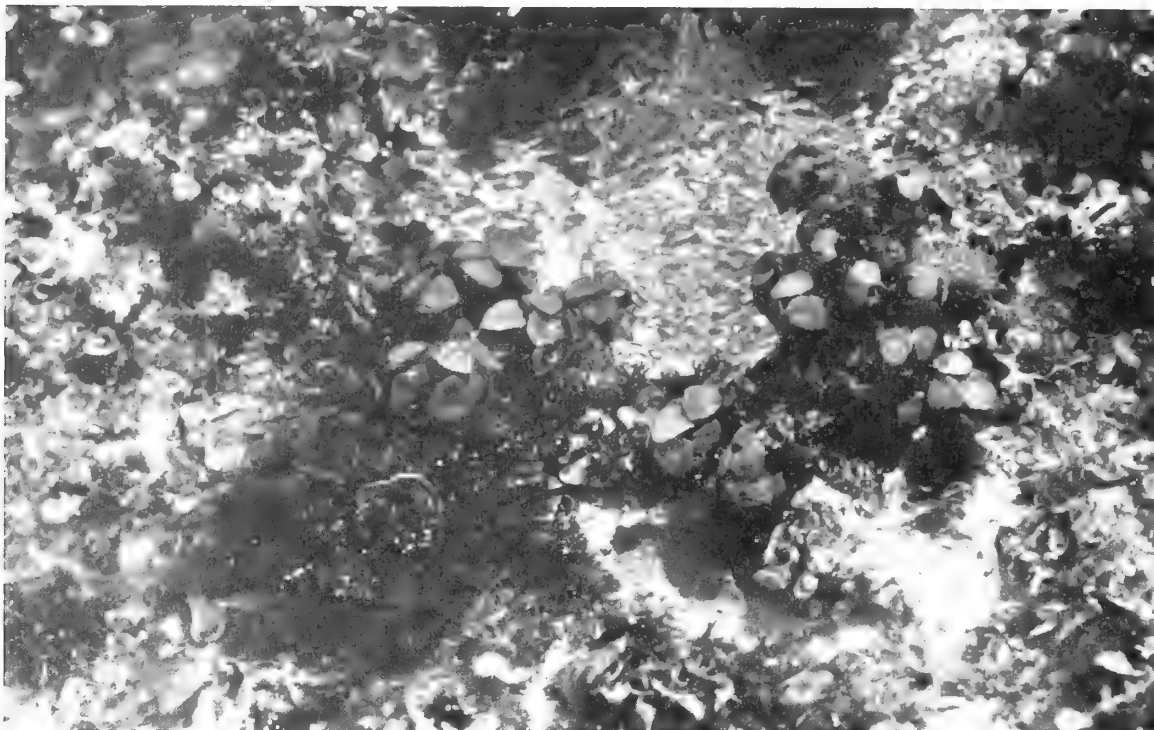


Plate 27. *Turbinaria turbinata*, *Padina sanctae-crucis* and *Dictyota* sp. in the lower midlittoral zone at West End Rocks



Plate 28. East End showing the steep and deeply dissected littoral region



Plate 29. The rubble ridge of South Hole Sound looking east.
In the foreground is a small plant of the black mangrove
Avicennia germinans



Plate 30. *Cittarium pica* on the jetty at Preston Bay

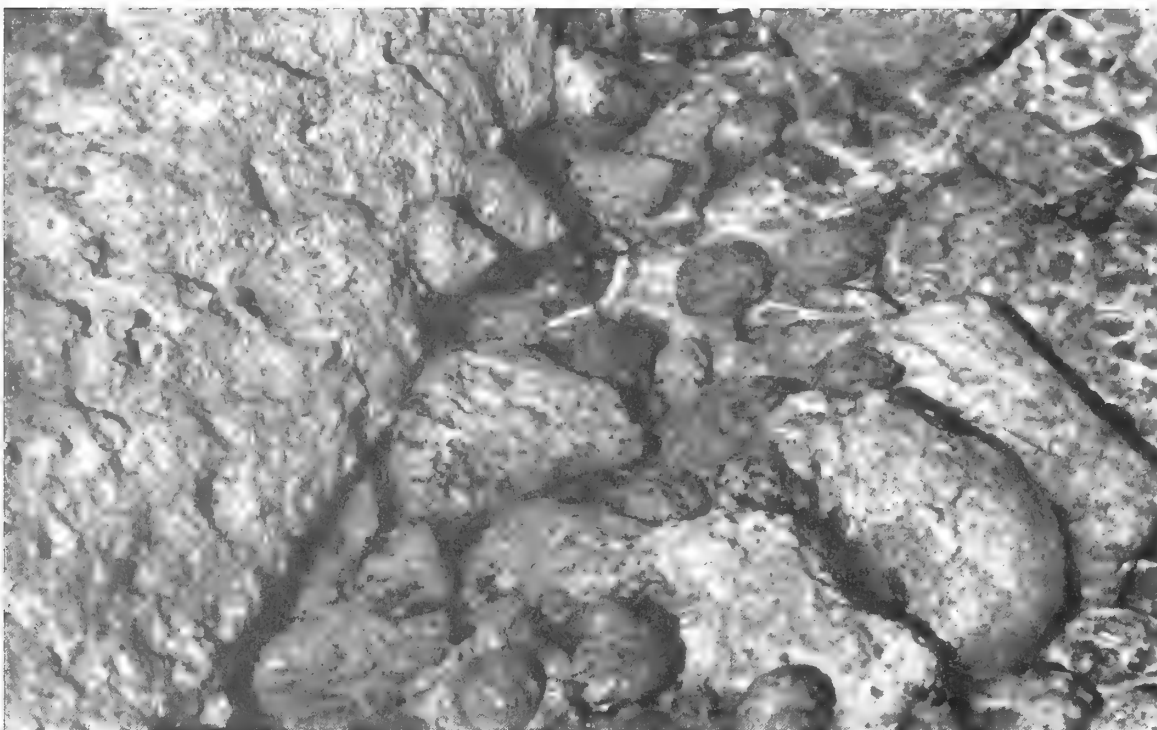


Plate 31. *Cittarium pica* covered in calcareous algae on the rubble ridge, South Hole Sound

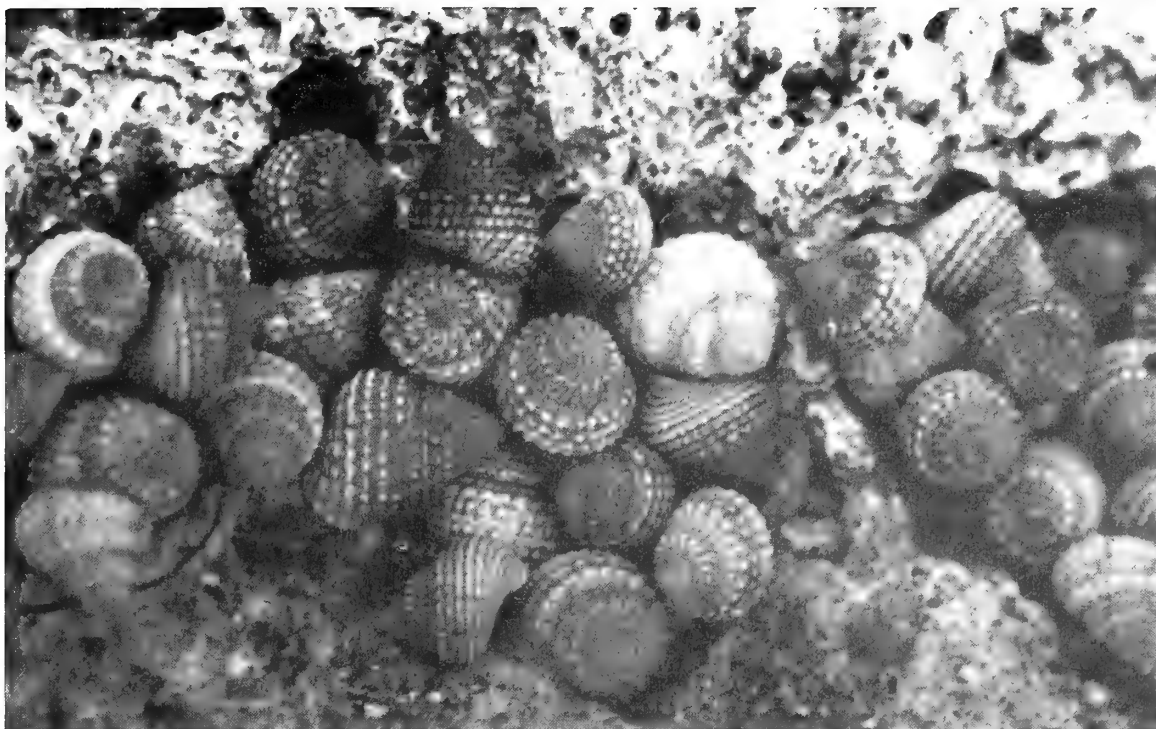


Plate 32. *Tectarius muricatus* in large numbers in the supralittoral fringe at East End



Plate 33. *Acanthopleura granulata* in shallow rock pools in the lower midlittoral zone

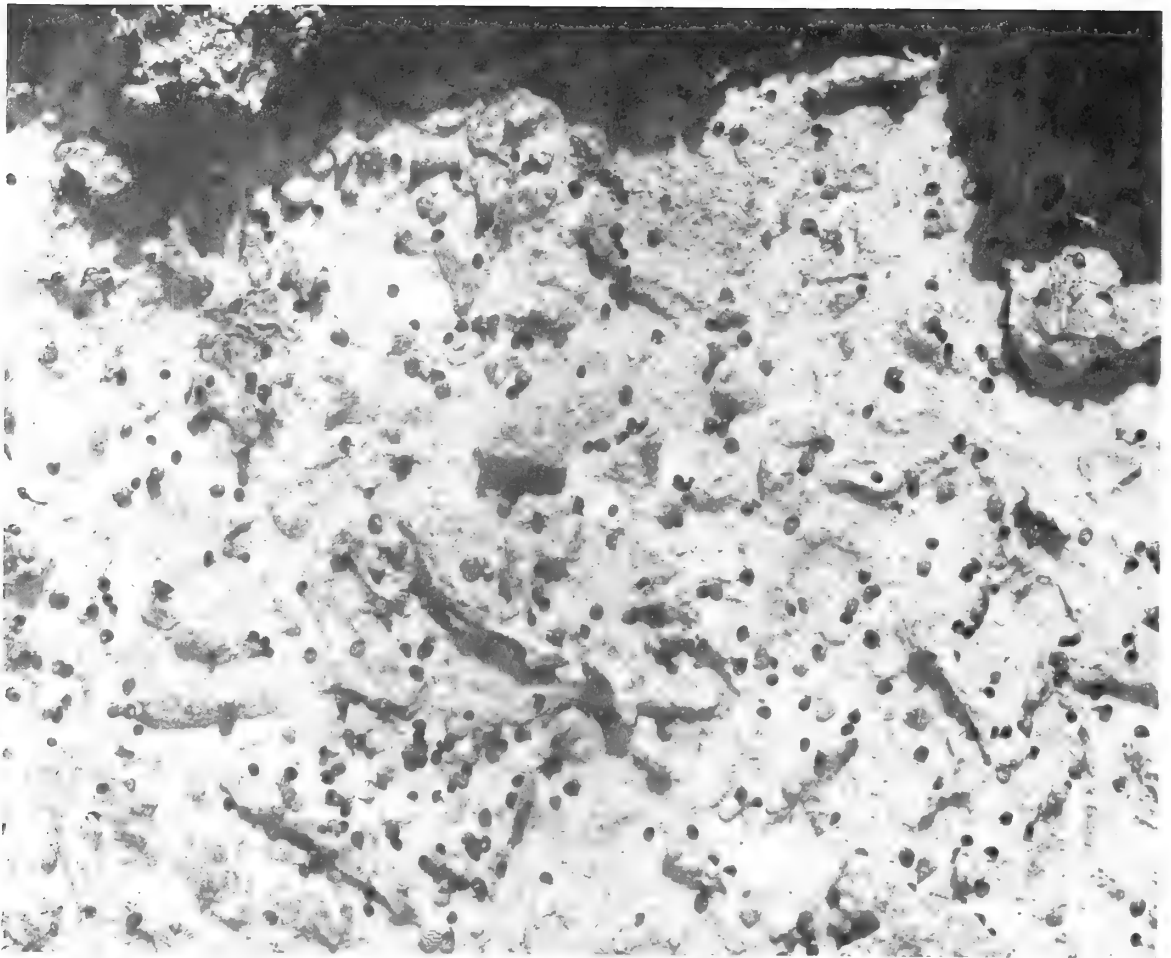


Plate 34. Rock pool at West End Rocks showing *Puperita pupa* and *Littorina mespillum* scattered over the bottom of the pool

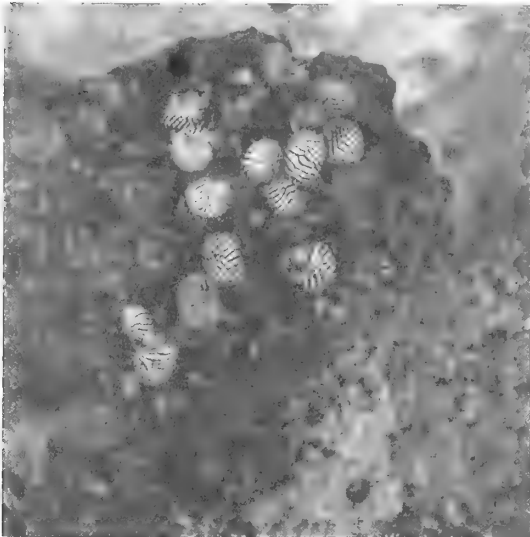


Plate 35. *Puperita pupa* gathered on a rocky pinnacle within a rock pool

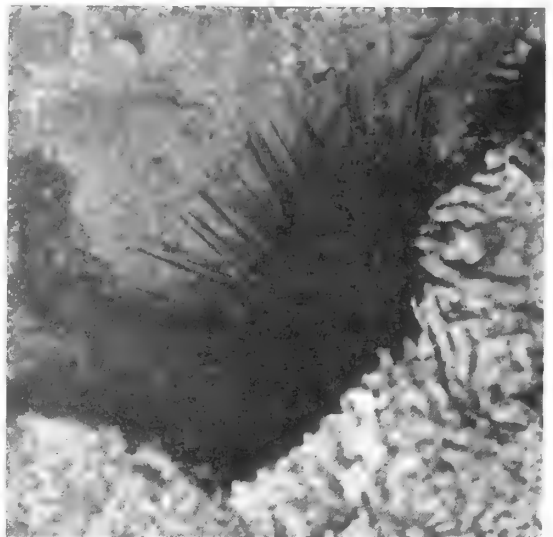


Plate 36. *Diadema antillarum* in a low tide level rock pool at Preston Bay

5. THE LITTORAL FISHES OF LITTLE CAYMAN (WEST INDIES)

G.W. Potts

Abstract

A brief survey of the littoral marine fish of Little Cayman is described together with notes of their habitat preferences.

The classification of littoral fish faunas in the Caribbean is discussed and an alternative scheme is suggested in the light of the present work. The fauna elements are typical of the area and support the theory that the Caribbean is an integrated zoogeographic unit.

Introduction

During the summer of 1975 the Royal Society and Cayman Island Government supported an expedition to Little Cayman where the opportunity was taken to study different aspects of the ecology of the island. The present paper examines the littoral marine fishes from two rocky shore areas, Jackson's Bay and the West End rocks from Little Cayman and describes their distribution and habitat preferences.

The distribution of littoral invertebrates has been well covered and is discussed and reviewed in special relation to Little Cayman by Potts (1979). By comparison the littoral fishes of the West Indies have not been examined in great detail apart from a few early papers by Breder (1948, 1954), and other works on single species such as those by Tavalga (1950a and b) and Aronson (1951, 1971) and others. For more general accounts of the shallow water fishes of the Caribbean it is necessary to examine the work by Longley and Hildebrand (1941) from the Tortugas, Florida with many useful ecological notes and the books by Beebe and Tee-van (1933), Randall (1968), and Bohlke and Chaplin (1968). The latter is especially useful in having a full bibliography of papers covering the taxonomy of fishes of the region. The Pacific coast of America and the islands of the topical Pacific have been examined by Hiatt and Strasburg (1960), Gosline (1965),

Thompson and Lehner (1976) and others and offer many useful ecological parallels and comparisons that will be discussed later.

Classification of Littoral Fishes

The littoral region of Little Cayman is described by Potts (1979) in a paper on the distribution and zonation of the common species of mollusc and crustacean. Potts also includes tidal data which show clearly that the low tidal range is less likely to have an effect on the distribution on littoral species than the surge and spray from wave action. While for the distribution of littoral invertebrates it has been convenient to adopt the classification and terminology outlined by Stephenson and Stephenson (1952) and which is summarised by Doty (1957), for the littoral fish it is more appropriate to use the classification of Gosline (1965) and Hiatt and Strasburg (1960). Gosline divides the littoral region into two; the "surge zone" which represents the true littoral region or midlittoral of Stephenson and Stephenson (1952) and which is washed by the surge action of waves as well as the normal rise and fall of sea level during the tidal cycle, and secondly the "splash zone" which is comparable with the supralittoral fringe and which is wetted only by spray from the action of wind and waves. Hiatt and Strasburg (1960) call these the 'intertidal' and 'supratidal' zones respectively.

This classification identifies the littoral region in terms of the influence of wave and tidal action on the shore. Within this framework the fish population has been considered under a further classification based upon the biological adaptation and permanence of the fish fauna to the region.

Breder (1948) described the littoral fish as either typical, casual or accidental, but these categories are not always easy to apply and it is perhaps somewhat easier to use Gibson's (1969) broader classification. In this, Breder's 'casual' and 'accidental' categories are grouped as 'partial residents', but in addition temporal variations are allowed for by the categories of 'tidal' and 'seasonal' visitors. In actual fact the partial residents could be either tidal or seasonal and it would seem more useful to define the fish as either residential or transient, and to subdivide the transient groups as either tidal or seasonal. This in fact covers most problems associated with the earlier classification, but leaves unresolved the need for a group to cover those species that may only occur in the littoral region at a certain stage of their ontogeny. To some extent this is covered by the heading of seasonal visitors, but this might better be divided into two to describe seasonal visitors that represent adult migrants and those which are present as part of their essential ontogeny. The revised classification recommended for littoral fish is briefly summarised in Table 5 and it is this classification that is adopted in the present work.

While this classification may assist to identify the relevance of a fish in the littoral zone it can only be used as a rough guide in the categorisation of spatial and temporal factors controlling littoral fish

populations. Variability in dependence upon the littoral environment will be species specific and a classification of this kind can only be of advantage in comparing between species at the broadest level.

Table 5. Classification of littoral fishes

I Residential Species

II Transient Species (a) Accidental visitors

(b) Tidal visitors

(c) Seasonal visitors (i) Adult migrants
(ii) Juveniles

Methods

The areas chosen for examination were at West End rocks in the west and at Jackson's Bay in the North of Little Cayman. The more exposed rock outcrops at the East End and bluff end of the island only contained relatively small pools on a steep shore and contained rather few species of littoral fish. For this reason it was decided to concentrate on the pools on the more sheltered sides of the island. Before pools were subjected to disturbance observations were made of the habits of the fish species present. This was then followed by a survey of the extent and depth of the pool.

Littoral fish were collected at low water by using the fish anaesthetic Quinaldine in the manner suggested by Gibson (1967). Firstly the rocks and larger stones were moved from the pool and then a mixture of Quinaldine mixed one to four with acetone was squirted into the pool from a plastic wash bottle. The mixture was directed into crevices in the rock where many of the smaller littoral species hide and the water was agitated thoroughly. As soon as fish showed signs of anaesthesia they were dipped out of the pool with a net and transferred to a bucket of clean sea water where they revived. It is interesting to note that as well as fish the stomatopods, *Pseudosquilla* sp. and *Gonodactylus* sp. were also affected by the Quinaldine and could be easily collected. The fish were then examined and provisional identifications made of the living specimens before they were narcotised and preserved in 10% Formalin. Figure 20 represents diagrammatically the fish faunas of the splash and surge level pools.

Results

A summary of the littoral fish collected on Little Cayman is given in Table 6 together with details of the mean size, sample size, zonal

Table 6. Table indicating the mean size, sample size and habitat preference of the fishes found occupying six littoral rock pools.

SPECIES	mean size (mm)	number of specimens	maturity	Habitat preference			Zonal level		residential sp.	transient sp.
				midwater	benthic	crevice	splash zone	surge zone		
Holocentridae										
<i>Adioryx vexillarius</i> (Poey)	53	13	A			*	*	*	*	*
Gobiidae										
<i>Bathygobius soporator</i> (Cuv. and Val.)	43	39	J-A		*	*	*	*	*	
Pomacentridae										
<i>Abudefduf taurus</i> (Müll. and Tros)	19	5	J	*			*			*
<i>A. saxatilis</i> (L)	24	17	J	*			*			*
<i>Eupomacentrus leucostictus</i> (Müll. and Tros)	31	1	J	*			*		*	*
Lutjanidae										
<i>Lutjanus apodus</i> (Walbaum)	29	5	J	*			*			*
Gerridae										
<i>Gerres cinereus</i> (Walbaum)	40	2	J	*			*			*
<i>Eucinostomus argenteus</i> (Baird & Girard)	28	4	J	*			*			*
Gobiescoidae										
<i>Tomiodon fasciatus</i> (Peters)	22	6	A		*	*	*	*	*	*
Tetradontidae										
<i>Canthigaster rostrata</i> (Bloch)	25	1	A	*	*			*		*

level and habitat preferences. The fish of the splash zone will include ones collected from the supralittoral fringe and upper part of the midlittoral zone while those of the surge zone are completely littoral and were found in pools down to the infralittoral fringe. Provisional field identification were made from the book by Chaplin and Scott (1972) and these were subsequently checked with the important reference books of Randall (1968) and Bohlke and Chaplin (1968).

Of the 15 species caught from 12 families, it is striking that only three species were found to occupy both the splash zone and the surge zone, *Bathygobius soporator*, *Abudefduf saxatilis* and *Tomicodon fasciatus*. It must be assumed that some species of the upper splash zone might normally be found in the surge zone pools since all but one are considered transient littoral species which at some stage will spend time offshore in the sublittoral region. By comparison none of the surge level species could be considered residential littoral species most of which are more commonly found on the fore-reef terrace and only the juveniles of *Thalassoma bifasciatum* were found with any regularity in littoral pools. Only *B. soporator* was confined to the littoral region and not seen below tide marks.

The habitat preferences of the species indicate that under undisturbed conditions they can be broadly grouped into those that swim in mid-water, benthic species that keep close to the rock often with the aid of anatomical adaptations such as modified fins, and those that tend to remain in crevices. There is some overlap between these groups as some benthic species may also use crevices and mid-water species may adopt them when disturbed, or at certain times of the day. There may also be ontogenetic differences not recognised during the present work. On the whole the crevice dwellers, e.g. *Muraenidae*, tend to be crepuscular or nocturnal in their habits.

The majority of species were immature and only *B. soporator*, *A. vexillarius*, *Tomicodon fasciatus* and *Canthigaster rostrata* were represented by adult specimens although even these were smaller than the adults shown in Randall (1958) and Bohlke and Chaplin (1968).

In addition to the species listed in Table 6 one other fish species was collected from West End rocks, *Diodon holacanthus*. this single mature specimen (315 mm) must be considered a transient pool species, as while not uncommon on the shallow upper reef terrace together with *D. histrix*, it does not normally tolerate the unstable pool environment. This specimen was found beneath a very large flat boulder which must have provided the shelter necessary for this relatively weak swimmer. Another species, the Hardhead silverside *Atherinomorus stipes* (mean total length 67 mm, ST = 8.1, n = 37) were found in a group of two or three hundred individuals in an inlet at West End rocks where they kept close to the waters edge on the rising tide. It is probable that this species may also be trapped in low level pools on the falling tide.

Quinaldine as well as narcotising the littoral fish also affected the stomatopods that were common in the littoral and sublittoral region. Two genera were collected, *Gonodactylus* sp. that was found in

splash and surge level pools and *Pseudosquilla* sp. found only in the lower surge pools.

Discussion

In temperate regions where the tidal range is often large, the littoral region may provide an extensive platform with large and permanent rock pools in which many species of fish are able to establish themselves. The fish fauna is further assisted by the development of a considerable algal canopy which offers a diverse habitat in which littoral fishes can live together with a large range of potential food organisms. By contrast the littoral region of tropical islands is often poorly developed with a small tidal range and relatively inconspicuous flora. Over much of the tropics the tidal range is less than one metre and the nature and extent of the shore and its associated fauna and flora are determined by the degree of wave action rather than by tidal factors (Doty, 1957; Hiatt and Strasburg, 1960 and Gosline, 1965). In addition, the physical environment necessitates that littoral fish are tolerant of temperature extremes and emersion, together with the related problems of oxygen tension, pH, salinity, and desiccation. These factors and other aspects of the adaptations shown by littoral fishes to life on shore are reviewed by Gibson (1969).

Apart from the early work of Breder (1948, 1954) most work on littoral fish faunas from the Caribbean has been done on specific aspects of the biology of single species. On Little Cayman the only permanent littoral resident was the Frillfin goby *Bathygobius soporator*, occurring at all tidal levels in rock pools. This fish has been subjected to more research than any other Caribbean species with important work on its locomotion and orientation by Aronson (1951, 1971), and upon other aspects of its life cycle and sensory biology by Tavolga (1950a and b). No large scale survey on the ecological relations of the fish fauna of the Caribbean has been published, of the kind carried out by Hiatt and Strasburg (1960) for the Marshall Islands, but none-the-less the books of Randall (1968) and Bohlke and Chaplin (1968) do provide much useful ecological information on individual species, together with descriptions of their known geographic ranges.

The Cayman group of islands lie in the deep water of the Cayman Trench between Jamaica and Cuba. For this reason the littoral fish fauna is particularly interesting as the problems associated with their dispersal across deep water are considerable and it might be expected that some form of endemism might occur among fish restricted to shallow water. In fact no unusual faunal elements were found among the shore fishes all of which are recorded from Cuba (Duarte-Bello and Buesa, 1973), and which confirms the view that the Caribbean can be regarded as an integrated zoogeographic unit with relatively free mixing among the fish population of the region. Despite this, Little Cayman had only four littoral fish common to those listed by Breder (1948) from Bimini in the Bahamas. These were the ubiquitous species *B. soporator*, *T. bifasciatum*, *E. leucostictus* and *Abudefduf saxatilis*. The remaining species were different, but represented similar families that are typical of the littoral region, both within the Caribbean area

and the tropical Pacific (Hiatt and Strasburg, 1960; Gosline, 1965 and Thompson and Lehner, 1976) and also to some extent the littoral zone from temperate regions (Gibson 1969). It seems that the colonisation of the turbulent and unstable littoral region has only been possible by relatively few families of fish which have been able to develop behavioural, anatomical and physiological adaptations appropriate to the littoral environment. Many of these adaptations are described and discussed in the papers mentioned above to which should be added the work of Fishelson (1963), Gibson (1967a and b) and Williams (1957).

While the littoral fish of Little Cayman are confined to a relatively restricted environment it can be seen by examining Table 6 that rather few are likely to be in competition for space or food as not only do they show different spacial and temporal activity patterns, but also differences in feeding habits. With the predominance of carnivorous species the situation is essentially similar to that of Californian tide pools described by Mitchell (1953).

On Little Cayman four species were identified as being residential in the littoral region. The others are typical of several groups of shallow water tropical fish which are widely distributed over the upper reef terraces and back reef including at times the littoral region. Other species formed a more transient element and were mostly represented by juvenile individuals of shallow sublittoral species. Some, such as *Abudefduf saxatilis*, *A. taurus*, *Lutjanus apodus* and *Tomicodon fasciatus* were relatively common in rock pools and it must be supposed that the young of these and other species of fish may remain in the shallow beach zone. In this region they would be protected from the predatory species that frequent the reef platform. Other species are widespread as the Holocentrid, *Adioryx vexillarius* which is common beneath boulders in rock pools and may also be found down to a depth of 20 m on the lower fore-reef terrace. Gibson (1969) also described a group of littoral fishes, the "seasonal visitors", which are represented only at specific times of the year, often associated with spawning migrations. Unfortunately, the brief period on Little Cayman did not permit a full examination of these species.

Acknowledgements

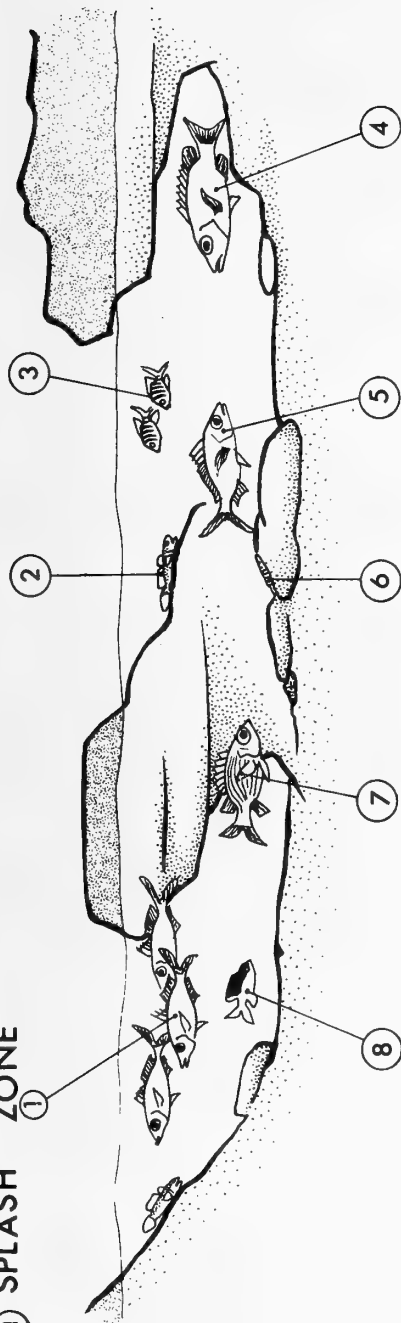
I should like to acknowledge the financial and other support given by the Royal Society and Cayman Island Government and in particular to Dr M.E.C. Giglioli and various members of his staff at the Mosquito Research and Control Unit. I should like to thank George Giglioli and Eugene Parsons for field assistance and Roger Swinfen for help with material after the return to the Plymouth Laboratory. I am grateful to the Director of the Marine Biological Association for permission to join the expedition. Lastly I should like to thank the other members of the expedition who helped in many ways.

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(a) SPLASH ZONE



(b) SURGE ZONE

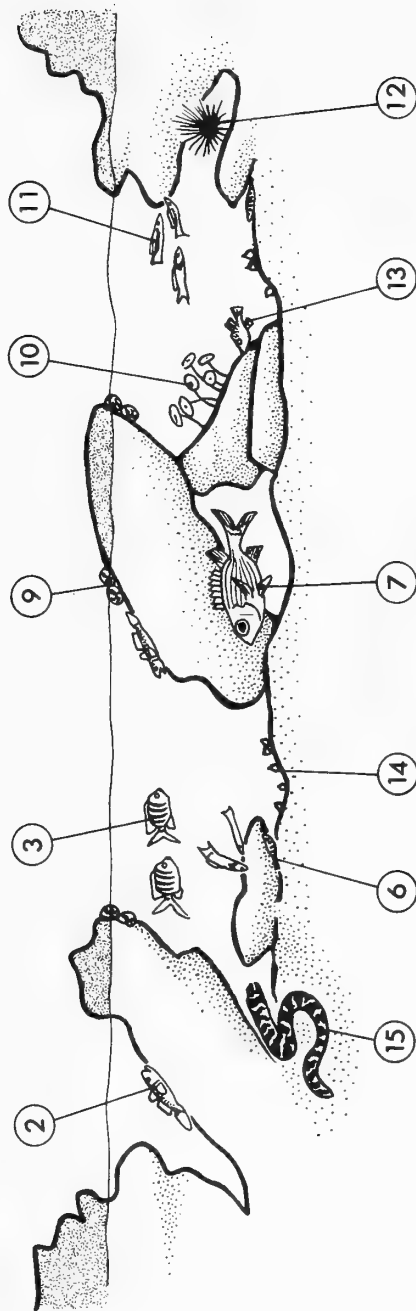


Figure 20. Diagram of (a) Splash Zone and (b) Surge Zone pools with their typical inhabitants: 1. *Eucinostomus argenteus*; 2. *Bathygobius soporator*; 3. *Abudefduf saxatilis*; 4. *Lutjanus apodus*; 5. *Gerres cinereus*; 6. *Tomicodon fasciatus*; 7. *Adioryx vexillarius*; 8. *Eupomacentrus leucostictus*; 9. *Puerita pupa*; 10. *Acetabularia sanctae-crucis*; 11. *Thalassoma bifasciatum*; 12. *Diadema antillarum*; 13. *Canthigaster rostrata*; 14. *Littorina mespillum*; 15. *Echidna catenata*

6. VEGETATION OF LITTLE CAYMAN

D.R. Stoddart

Although the vegetation of Little Cayman has not been previously described, the island belongs to the class of low, dry, limestone islands in the Caribbean which has attracted much attention. Beard (1944, 1949, 1955) provides a classification of the vegetation and descriptions of the Windward and Leeward Islands which many subsequent workers have used as a model. Similar treatments have been provided for limestone areas in Jamaica (Asprey and Robbins 1953, Loveless and Asprey 1957, Asprey and Loveless 1958), Cuba (Seifrizz 1943, Howard and Briggs 1953), Antigua (Loveless 1960, Harris 1965), Barbuda (Harris 1965, Stoddart, *in litt.*), Anguilla (Harris 1965), and Anegada (D'Arcy 1971, 1975). Coastal strand vegetation similar to that of Little Cayman has been widely described in the Caribbean and the Gulf of Mexico (Sauer 1959, 1967, Poggie 1962). Dr J.D. Sauer has included three Little Cayman transects in a study of coastal vegetation of the Cayman Islands which he began in 1962 and which will in due course lead to a major publication.

This chapter is divided into four parts on a largely empirical basis. The first treats inland vegetation communities on limestone, the second coastal communities, and the third mangrove communities. Beard's scheme is followed for the limestone areas, though it seems less appropriate for coastal vegetation and covers mangrove communities only in broad outline. The fourth section outlines a classification of terrestrial habitats of broad ecological significance on Little Cayman (Figure 21).

A. Inland communities on limestone

The vegetation of Little Cayman, other than the coastal and swamp communities, falls within the general class of Dry Evergreen Formations recognised by Beard (1944), extended and defined by Beard (1949), and revised by Beard (1955). Dry Rain Forest, originally termed Xerophytic Rain Forest (Beard 1944), is not found in the Cayman Islands. Four other types can, however be recognised: Dry Evergreen Forest, Dry

Evergreen Woodland, Dry Evergreen Thicket, and Evergreen Bushland. In a continually varying and also little known and generally inaccessible vegetation such as that of Little Cayman, where communities are floristically diverse but where many species are represented in different vegetation types, it is difficult to assign limits to these categories. Harris (1965) found a similar difficulty in Antigua, Anguilla and Barbuda (though all these islands have vegetation much modified by man), and combined the Dry Evergreen Woodland and Evergreen Bushland in a single category of Evergreen Woodland. Some confusion also arises from the fact that Asprey and Robbins (1953, 380-383) describe a Dry Limestone Scrub Forest with *Bursera* as an emergent, which clearly has parallels in Little Cayman, but equate it with Beard's Semi-Evergreen Seasonal Forest, one of his Seasonal rather than Dry Evergreen Formations. A variant of their category of Dry Limestone Scrub Forest is an Arid Limestone Scrub Forest on dissected coastal limestone (1953, 383-384), which also has Cayman counterparts.

1. Dry Evergreen Forest

Beard (1949, 80) did not originally describe this type in detail because "the bulk of the woodland which appears to belong to this type is very heavily damaged and it is not possible to form any reliable conception of the original structure"; he associated it with mean annual rainfalls of 1270-2000 mm, higher than those of Little Cayman. Tall woodland in the interior of Little Cayman, south of Sparrowhawk Hill (Plate 37), meets Beard's (1955, 92) diagnosis of "crowded, slender trees reaching 12 to 20 metres in height above which an occasional emergent reaches 30 metres. Leaves are simple and evergreen, the majority being stiff and fleshy, a high proportion with latex or essential oil. Bark-shedding may be a conspicuous feature. The shrub and herb layers are poorly represented." The forest occurs on a flat-lying limestone area about 4-5 m above sea-level. The ground surface is undissected, and has a considerable soil and litter cover. The dominant big trees are *Bumelia salicifolia*, *Calypttranthes pallens* and *Chionanthus* sp., forming a canopy at 8-10 m. In spite of their height, most of the trees are slender and closely-spaced. A number of shrubby species are present, but the forest is relatively open and easy to walk through. The following species were noted:

Trees:	<i>Bumelia salicifolia</i>	<i>Croton nitens</i>
	<i>Bursera simaruba</i>	<i>Erythroxylum rotundifolium</i>
	<i>Calypttranthes pallens</i>	<i>Hypelate trifoliata</i>
	<i>Canella winterana</i>	<i>Myrcianthes fragrans</i>
	<i>Chionanthus</i> sp.	<i>Tabebuia heterophylla</i>
Shrubs:	<i>Allophylus cominia</i>	<i>Croton lucidus</i>
	<i>Amyris elemifera</i>	<i>Jacquinia berterii</i>
	<i>Argythamnia proctorii</i>	<i>Malvaviscus arboreus</i>
	<i>Chiococca alba</i>	<i>Maytenus buxifolia</i>
	<i>Colubrina elliptica</i>	<i>Randia aculeata</i>
Herbs:	<i>Lasiacis divaricata</i>	<i>Paspalum blodgettii</i>

Succulent: *Agave sobolifera*

Epiphytes: *Schomburgkia brysiiana* *Tillandsia* spp.

The *Agave* is rare, and cacti are apparently absent, as are ferns. The limits of the forest are conjectural, but probably coincide with the 20 ft contour south of Sparrowhawk Hill on the 1:25,000 map. Northwards the forest ends in a limestone ridge covered with Dry Evergreen Thicket; to the south and east it passes into dissected low-lying limestone terrain with *Conocarpus* and *Laguncularia* scrub.

2. Dry Evergreen Woodland

This is described by Beard (1955) as a two-storey woodland of densely packed attenuated trees forming a canopy at 6-12 m, with emergents reaching 20 m; it is not very clearly distinguished from Dry Evergreen Forest. In 1955 Beard equated it with Littoral Woodland, but it is more useful here to maintain the latter as a separate component of coastal vegetation.

Dry Evergreen Woodland is used here to denote a more open and lower woodland than Dry Evergreen Forest, characteristically found on gently sloping terrain associated with the Marl Facies of the Ironshore Formation (Plate 39). Much of the surface is bare rock, but it is relatively undissected, and where the Marl Formation gives way to dissected Bluff Limestone there is an abrupt transition from Dry Evergreen Woodland to Dry Evergreen Thicket. The woodland is also found in more protected situations, such as northwest, west and south-facing slopes. The woodland is found on terrain rising to 6.5 m above sea-level at Paradise End (045781), to 12.5 m inland from Jackson's Bay (977767), and to 13 m inland from Salt Rocks (944749). The most conspicuous tree species is *Bursera simaruba*. Characteristic species of Dry Evergreen Thicket, such as *Plumeria obtusa*, *Cephalocereus* and *Agave*, are inconspicuous in the woodland. Inland from Salt Rocks, the woodland extends down to the coast (in most areas it is separated from the coast by a zone of lagoon, swamp and beach ridge), and the following species were noted:

Trees:	<i>Bursera simaruba</i>	<i>Ficus aurea</i>
	<i>Canella winterana</i>	<i>Guapira discolor</i>
	<i>Citharexylum fruticosum</i>	<i>Metopium toxiferum</i>
	<i>Coccoloba uvifera</i>	<i>Picrodendron baccatum</i>
	<i>Cordia gerascanthus</i>	<i>Tabebuia heterophylla</i>
	<i>Cordia sebestena</i>	<i>Trichilia glabra</i>
	<i>Croton nitens</i>	<i>Swietenia mahagoni</i>
Shrubs:	<i>Adelia ricinella</i>	<i>Jacquinia berterii</i>
	<i>Argythamnia proctori</i>	<i>Malvaviscus arboreus</i> var.
	<i>Ateramnus lucidus</i>	<i>cubensis</i>
	<i>Calyptranthes pallens</i>	<i>Maytenus buxifolia</i>
	<i>Capparis flexuosa</i>	<i>Phyllanthus angustifolius</i>
	<i>Coccothrinax jamaicensis</i>	<i>Savia erythroxylodes</i>
	<i>Colubrina elliptica</i>	

Vines: *Capparis flexuosa* *Ipomoea macrantha*
 Ipomoea acuminata

Grass: *Lasiacis divaricata*

Many of the tree species are identical with those of the Dry Evergreen Forest; some, notably *Coccoloba uvifera* and *Cordia sebestena*, are present only because of the coastal situation of this locality and are not present elsewhere in Dry Evergreen Woodland.

3. Dry Evergreen Thicket

This vegetation type, one of the most common on Bluff Limestone of Little Cayman, did not appear in Beard's earlier classifications and was first recognised by him in 1955; in that paper, however, he did equate it with his earlier categories (1944) of Littoral Thicket and Littoral Hedge, though it is more convenient in the case of Little Cayman to treat these latter separately as component of coastal vegetation. Beard described Dry Evergreen Thicket as a two-storey thicket "with a low, open, or dense canopy and a dense or sparse undergrowth". The canopy is at 6-12 m, with occasional emergents, and the trees are slender. Dry Evergreen Thicket has been further described from south Jamaica, with a canopy at 5-11 m and emergents to 16 m (Loveless and Asprey 1957, 813-815), and from Antigua, where it comprises "a dense shrub layer about 2-4 m (7-13 ft) high, overtopped by scattered but more or less uniformly distributed trees reaching a height of 7-8 m (23-26 ft)", with *Agave*, *Opuntia* and *Cephalocereus* (Loveless 1960, 511-513). In Antigua it occurs in areas with a mean annual rainfall of less than 900 mm.

Dry Evergreen Thicket as previously recognised is thus a rather variable entity, and on Little Cayman it also varies in height, density and composition, at least partly in response to aspect and exposure (Plate 38).

(a) Seaward slopes of Bluff Limestone ridges

Along much of the north-facing coast of Little Cayman there is a flat terrace or gently slope of dissected Bluff Limestone 150-200 m wide and rising up to 5 m above sea-level, situated between the coastal swamp and the Bluff Limestone ridge, covered with open Dry Evergreen Thicket. Trees are only 3-4 m tall, and as in the case of *Bursera simaruba* may be severely deformed above this level. Three other very characteristic taller species are *Plumeria obtusa*, *Cephalocereus swartzii* and *Agave sobolifera* (Plate 40). *Guapira discolor* is a very common tree, and *Savia erythroxylodes* the most abundant shrub. This open thicket is very similar to that described from the northern Lesser Antilles, e.g. Barbuda, except that the spherical cacti *Melocactus intortus* and *Mammillaria nivosa* are absent from the Cayman Islands.

The following species were noted in this habitat on the northern side of Sparrowhawk Hill (003781):

Trees:	<i>Guapira discolor</i>	<i>Plumeria obtusa</i>
	<i>Guettarda elliptica</i>	<i>Tabebuia heterophylla</i>
	<i>Myrcianthes fragrans</i>	
Shrubs:	<i>Amyris elemifera</i>	<i>Evolvulus arbuscula</i>
	<i>Bauhinia divaricata</i>	<i>Jacquinia berterii</i>
	<i>Calyptranthes pallens</i>	<i>Phyllanthus nutans</i>
	<i>Croton linearis</i>	<i>Randia aculeata</i>
	<i>Croton lucidus</i>	<i>Savia erythroxyloides</i>
	<i>Erithalis fruticosa</i>	<i>Strumpfia maritima</i>
Succulents:	<i>Agave sobolifera</i>	<i>Cephalocereus swartzii</i>

(b) Dissected Bluff Limestone ridge

The Bluff Limestone ridge is a linear feature, parallel to the north coast, reaching its greatest elevations of 6-13 m about 200-400 m inland. It is deeply dissected, with many depressions more than 2 m deep, and with cliff faces of the same amplitude. The thicket is more dense than on the seaward slopes, and there are more tree species identical with those of Dry Evergreen Forest and Dry Evergreen Woodland. The littoral shrub *Strumpfia maritima* disappears, but *Bursera*, *Plumeria*, *Cephalocereus* and *Agave* remain characteristic. The following species were noted at Sparrowhawk Hill (004780):

Trees:	<i>Bursera simaruba</i>	<i>Hypelate trifoliata</i>
	<i>Canella winterana</i>	<i>Myrcianthes fragrans</i>
	<i>Cordia gerascanthus</i>	<i>Plumeria obtusa</i>
	<i>Cordia sebestena</i>	<i>Schoepfia chrysophylloides</i>
	<i>Guapira discolor</i>	<i>Tabebuia heterophylla</i>
	<i>Guettarda elliptica</i>	
Shrubs:	<i>Bauhinia divaricata</i>	<i>Phyllanthus angustifolius</i>
	<i>Calyptranthes pallens</i>	<i>Savia erythroxyloides</i>
	<i>Erithalis fruticosa</i>	<i>Tournefortia volubilis</i>
	<i>Jacquinia berterii</i>	
Succulents:	<i>Agave sobolifera</i>	<i>Cephalocereus swartzii</i>
Epiphytes:	<i>Schomburgkia brysiانا</i>	<i>Tillandsia</i> spp.

(c) Inland slopes of Bluff Limestone ridge

The inland slopes of the Bluff Limestone ridge are of variable steepness and height, and in places cliffy. Their main characteristic, however, is that they are much more protected than seaward-facing slopes, and this results in taller, denser thicket with many more epiphytes. The vegetation of this habitat at Sparrowhawk Hill is adjacent to the Dry Evergreen Forest of the centre of the island and it includes tall trees of species common to that woodland (*Bumelia*, *Amyris*, *Chionanthus*). Species present include:

Trees:	<i>Allophylus cominia</i>	<i>Bumelia glomerata</i>
	<i>Amyris elemifera</i>	<i>Bumelia salicifolia</i>
	<i>Antirhea lucida</i>	<i>Chionanthus</i> sp.
	<i>Ficus aurea</i>	<i>Plumeria obtusa</i>
	<i>Guapira discolor</i>	<i>Tabebuia heterophylla</i>
	<i>Guettarda elliptica</i>	<i>Zuelania quidonia</i>
	<i>Myrcianthes fragrans</i>	
Shrubs:	<i>Bauhinia divaricata</i>	<i>Gyminda latifolia</i>
	<i>Bourreria venosa</i>	<i>Jacquinia berterii</i>
	<i>Colubrina asiatica</i>	<i>Phyllanthus nutans</i>
	<i>Croton linearis</i>	<i>Randia aculeata</i>
Herbs:	<i>Paspalum blodgettii</i>	<i>Salvia occidentalis</i>
Succulents:	<i>Agave sobolifera</i> (rare)	
Epiphytes:	<i>Schomburgkia brysiana</i>	<i>Tillandsia</i> spp.

4. Evergreen Bushland

This category was introduced by Beard in 1949 (82-84), taking the vegetation of Barbuda as a type example. Beard quoted Warming's (1909) description of "a grey, desolate, useless and scorching bushland between whose thorny tangled shrubs and low trees one cannot penetrate without the use of an axe" (a description which also applies to much of the Dry Evergreen Thicket). Evergreen Bushland forms a low woodland, 3-9 m tall, consisting of a "dense impenetrable growth of gnarled, little trees and bushes with hard evergreen leaves". On Barbuda the trees include *Tabebuia pallida*, *Buceras bucida* and *Guettarda scabra*, with bromeliads (though no mosses or ferns), *Agave* and cacti. D'Arcy (1975) assigns the vegetation of Anegada to this category, though it has been heavily disturbed by grazing; according to Beard (1949) the sub-climaxes resulting from disturbance of Evergreen Bushland are various thorny thickets. Evergreen Bushland is also described by Loveless and Asprey (1957, 809-813) from south Jamaica, where it has a uniform height of 4 m, with emergents (mainly *Bursera*) reaching 7-8 m, and by Loveless (1960) from Antigua.

Evergreen Bushland covers much of the western end of Little Cayman, on undulating but generally low and moderately dissected terrain; very low and heavily dissected limestone in contrast is covered with *Conocarpus* scrub. It is well seen along the trans-island track north of Blossom Village, where the land lies at 2-3 m above sea-level. This area has certainly been much modified by grazing and cultivation, but it is not possible to estimate the effect of this on the vegetation. *Plumeria*, *Agave* and *Bursera* are present but much less conspicuous than elsewhere. Shrubs include *Jacquemontia berterii*, *Evolvulus arbuscula* and *Strumpfia maritima*, together with many weedy species. Clumps of the leather fern *Acrostichum aureum* nestle in solution holes (Plate 41) in the limestone in exactly the same way as Fosberg (1971) has described for Aldabra Atoll; usually this fern (which is the only one recorded for Little Cayman) is associated with sea-level mangrove swamps.

B. Coastal vegetation

In addition to swamp vegetation, mainly mangrove, in coastal situations, Beard (1949, 84-87) distinguished as one of his Dry Evergreen Formations the category of Littoral Woodland as "a series of closely associated formations", including Littoral Hedge, with several sub-climaxes (sand dune, salt flats, rock pavements, rocky slopes). Subsequently he equated (1955) Littoral Woodland with Dry Evergreen Woodland, and Littoral Thicket and Littoral Hedge with Dry Evergreen Thicket. Asprey and Loveless (1958) in north Jamaica separated coastal rock from coastal sand communities, within the general category of Littoral Woodland. This division was broadly followed by Loveless (1960), in Antigua, who, however, considered strand communities to be edaphic climaxes rather than seral stages of the kind envisaged by Davis (1942), Asprey and Robbins (1953) and Beard (1949). The Asprey and Loveless scheme included:

On sandy substrates:

- Herbaceous pioneer
- Strand scrub
- Strand woodland

On rocky substrates:

- Littoral rock pavement
- Littoral hedge
- Littoral evergreen bushland
- Littoral palm thicket

The distinction between Littoral Hedge and Strand Scrub is not a clear one on Little Cayman; and a single category for Littoral Rock Pavement vegetation, though adopted by Howard (1950) in variable terrain, cannot properly encompass the topographic and vegetational variation found in rocky coastal situations. Here we use a purely empirical scheme specific to Little Cayman:

- Strand community on sandy beach
- Strand community on cobble beach
- Coastal sand flats
- Rock pavement community
- Steep rocky coast community

1. Strand community on sandy beach

Beaches on Little Cayman are variable in width and height, but most are protected by offshore reef and are low and narrow. Offshore beachrock indicates limited beach retreat in recent years round much of the coast. Ten sand beach areas were studied (Figure 3), and the following species were represented:

Trees:	<i>Avicennia germinans</i>	<i>Laguncularia racemosa</i>
	<i>Casuarina equisetifolia</i>	<i>Morinda citrifolia</i>
	<i>Coccoloba uvifera</i>	<i>Rhizophora mangle</i>
	<i>Cocos nucifera</i>	<i>Terminalia catappa</i>
	<i>Cordia sebestena</i>	<i>Thrinax radiata</i>
Shrubs:	<i>Borrchia arborescens</i>	<i>Scaevola plumieri</i>
	<i>Caesalpina</i> sp.	<i>Suriana maritima</i>
	<i>Colubrina asiatica</i>	<i>Mallotonia gnaphalodes</i>
	<i>Conocarpus erecta</i>	
Herbs:	<i>Ambrosia hispida</i>	<i>Ipomoea macrantha</i>
	<i>Cakile lanceolata</i>	<i>Ipomoea pes-caprae</i>
	<i>Canavalia rosea</i>	<i>Philoxerus vermicularis</i>
	<i>Cassytha filiformis</i>	<i>Salicornia bigelovii</i>
	<i>Euphorbia mesembrianthemifolia</i>	
	<i>Hymenocallis latifolia</i>	<i>Sesuvium portulacastrum</i>
Grasses and sedges:	<i>Cenchrus echinatus</i>	<i>Spartina patens</i>
	<i>Cyperus</i> spp.	<i>Sporobolus virginicus</i>

Where the natural vegetation has not been cleared, the beach crest is typically occupied by a 'Littoral Hedge', which as defined by Beard (1949, 84) "consists of a dense matted, and interlaced, woody growth of gnarled bushes usually of distorted form. Their height is variable, from a few inches to several feet, depending upon the force of the wind and available soil depth". As used by Asprey and Loveless (1958) in north Jamaica, the term is confined to rocky shores, where the hedge comprises many species, is 60 cm to 2 m tall, is wind-sheared in profile, and cut into windrows in plan. 'Littoral hedge', however, describes perfectly the appearance of the zone of *Coccoloba uvifera* at the beach crest, reaching 5 m in height but usually less than 50 m wide. It is wind-sheared in profile but not cut into windrows (Plate 42). It forms a dense and impenetrable scrub, with the ground surface devoid of other plants but covered with drying *Coccoloba* leaves. It corresponds to and in appearance closely resembles the *Scaevola taccada* hedge described from many Indo-Pacific atolls (e.g. Stoddart 1971, 135; 1975, 98). Trees of *Terminalia catappa*, *Cordia sebestena* and *Cocos* are occasionally found in the *Coccoloba*, but the hedge is essentially monospecific, in contrast to the array of species originally described from this community by Beard (1949, 85); some of Beard's species (*Chrysobalanus icaco*, *Erithalis fruticosa*) are present in Little Cayman, but not as a component of the littoral hedge.

Between the *Coccoloba* hedge and the sea there may be a shrub zone of variable width, dominated by *Suriana maritima*; this may be only the width of a single shrub, or in protected situations (as at West Point) it forms a scrub 2 m tall and 50-100 m wide. *Tournefortia* (*Mallotonia*) and *Scaevola plumieri* are occasionally present as scattered shrubs 1-2 m tall, but *Sophora tomentosa* has yet to be recorded on the island, though present on Grand Cayman.

Where undisturbed, the *Coccoloba* woodland and *Suriana* scrub reach down to the swash line, and pioneer herbaceous species are absent. At Sandy Point in the southeast (086785), however, the beach is aggrading and there is a more open mosaic of shrubs (*Scaevola*, *Tournefortia*, *Suriana*, *Caesalpinia*), occasional *Cordia*, and a patchy ground cover of pioneer *Cakile lanceolata*, *Sesuvium portulacastrum* and *Sporobolus virginicus*, with, inland, *Ipomoea macrantha*, *Euphorbia mesembrianthemifolia*, *Hymenocallis litorea*, and *Cenchrus* (Plate 43). Where the *Coccoloba* hedge has been cleared, a similar diverse mosaic of shrubs, herbs and grasses is developed. Common species are *Sesuvium*, *Ipomoea pes-caprae*, *Spartina patens* and *Sporobolus* at the beach crest, and, on the berm, *Sesuvium*, *Philoxerus*, *Ambrosia*, *Ipomoea macrantha*, *Cenchrus*, *Hymenocallis*, and the following shrubs: *Suriana*, *Scaevola*, *Tournefortia*, *Borrchia arborescens*, *Conocarpus erecta*, and low *Coccoloba*. There are young trees of *Casuarina equisetifolia* along the beach at Wearis Bay, but no mature groves of these trees on Little Cayman, in contrast to Grand Cayman where it forms a distinctive though restricted coastal woodland.

Notable variants of the above patterns occur at two main localities, round Bloody Bay on the north coast, and both east and west of Diggary's Point on the south, as well as occasionally elsewhere. Here, in protected situations, the coast is formed of alternating small low projections, consisting of rubble or rocky outcrops, and intervening bays with narrow low sandy beaches. The promontories support small patches of scrub of *Conocarpus* and *Laguncularia*, with occasional *Avicennia* and *Rhizophora*, and a herb mat of *Sesuvium*, *Philoxerus* and *Salicornia*. The sandy intervening bays have an irregular scrub of *Borrchia*, *Conocarpus* and *Suriana*, with *Sesuvium* and *Spartina patens*. Similar vegetation is found in the eastern part of South Hole Sound where the coast is not fringed by mangroves.

2. Strand community on cobble beach

This is difficult in many places to distinguish from the sand beach community, because in many places a modern sand beach fronts an older cobble and rubble ridge, so that frequently there is a zonation of sandy communities closest to the sea and of cobbles a few metres inland. *Suriana maritima* is often associated with the sandy strips or pocket beaches, and *Coccoloba* with the cobble ridges. Greatest diversity is found on the sand patches, which carry *Ambrosia*, *Ipomoea*, *Sesuvium*, *Hymenocallis* and *Borrchia*. Associated with *Coccoloba* on cobbles are *Morinda*, *Thespesia* and *Hymenocallis*. Where the scrub has been cleared from this rough terrain, the vegetation usually consists of thick deceptive mats of *Sesuvium*, *Ambrosia* and *Cassytha*.

3. Coastal sand flats

These form a laterally continuous zone (except for the Bluff Limestone outcrop at East End and the Salt Rocks Ironshore at the west end) round the entire island. The surface slopes gradually inland from the beach-ridge crest, and may be irregular because of the presence of either blown sand or rubble lobes. The flats are usually 50-100 m wide,

and never more than 200 m, and they are usually less than 2.5 m above sea-level. Except for a section of tall woodland at Spot Bay (950757), all the coastal flats have been cleared at some stage and are now occupied by secondary scrub, coconut plantation, or newly cleared ground. The Spot Bay woodland is probably the last surviving remnant of Littoral Woodland on any of the three Cayman Islands, and is thus of considerable interest. It includes tall trees of *Swietenia mahagoni* (reaching 15 m), and *Bursera simaruba*, with *Dalbergia ecastaphyllum*, *Cordia sebestena*, *Terminalia*, *Coccoloba uvifera*, and *Jacquinia berterii*. *Coccoloba* forms a hedge along the seaward side.

The secondary scrub consists of strand shrubs and trees (*Suriana*, *Tournefortia*, *Coccoloba*, *Cordia*, *Chrysobalanus*, *Conocarpus*), together with abundant *Lantana*, *Colubrina asiatica*, *Gossypium*, *Caesalpinia*, and some *Comocladia dentata*. At Jackson's Bay (976771) *Conocarpus* reaches a height of 5 m, *Suriana* and *Coccoloba* 3-4 m, and *Caesalpinia* 2 m. In places this secondary scrub is extremely dense. Elsewhere it is interrupted by more open ground, where strand herbs and grasses (*Euphorbia mesembrianthemifolia*, *Ipomoea pes-caprae*, *Cyperus* spp., *Ambrosia*, *Ernodea littoralis*, *Cassytha*, *Canavalia*, *Sporobolus*) are joined by weedy species such as *Bryophyllum*, *Abrus*, *Portulaca* and *Stachytarpheta*. *Rhynchelytrum repens* is conspicuous along roadsides, especially in the northeast, and is evidently a recent coloniser since it was not recorded by the Oxford Expedition in 1938.

Coconut plantations are limited to the west of Blossom Village, to Crawl Bay, to Owen Island, and to a few groves in other localities. Bud-rot disease has been present on Little Cayman since 1913, and many trees are dead and decapitated, especially near Blossom Village and on Owen Island (Plates 44 and 45). Owen Island itself (Figure 22) is covered partly by coconut plantation, partly by a dense scrub of discrete patches of *Coccoloba* (up to 8 m tall), *Laguncularia* and *Cordia*, with *Conocarpus* and *Thespesia* and scattered *Thrinax*. Areas near the shores have a low scrub of *Borrchia*, *Tournefortia*, *Conocarpus* and *Colubrina*, and there are small groves of *Rhizophora* and *Avicennia* on sheltered beaches. The herbaceous ground cover in the coconut plantation is diverse. *Melanthera aspera* and *Wedelia trilobata* are very common, as are the following species:

<i>Ambrosia hispida</i>	<i>Ipomoea macrantha</i>
<i>Boerhavia erecta</i>	<i>Ipomoea pes-caprae</i>
<i>Canavalia rosea</i>	<i>Melanthera aspera</i>
<i>Cenchrus</i> sp.	<i>Philoxerus vermicularis</i>
<i>Cyperus</i> sp.	<i>Portulaca oleracea</i>
<i>Euphorbia mesembrianthemifolia</i>	<i>Sesuvium portulacastrum</i>
<i>Hymenocallis litorea</i>	<i>Wedelia trilobata</i>

Recently cleared ground is extensive along the shores of Bloody Bay, from Bloody Bay Point to Jackson's Bay, and of Wearis Bay. The ground is being colonised by weedy species; clearing of trees and shrubs has been complete, except for mature trees of *Swietenia mahagoni* which have been left standing.

All human settlements on Little Cayman are located on the coastal sand flats, and with a very few exceptions the houses are grouped in Blossom Village. There is a common assemblage of introduced decorative plants around the houses, including *Crinum*, *Zephyranthes*, *Bougainvillea* and *Catharanthus*, with tall trees of *Terminalia*, *Cocos* and *Casuarina*.

4. Rock pavement (Ironshore outcrop)

"Littoral rock pavement" vegetation was described by Beard (1955) and subsequently by Asprey and Loveless (1958) in north Jamaica and by Loveless (1960) in Antigua. Somewhat inappropriately, however, they applied the term "rock pavement" to steep rocky slopes, ledges and terraces, often forming cliffs or ramps, rather than horizontal rock platforms. The term is much more suitable for the two main areas of flat Ironshore pavement which outcrop on the Little Cayman coast: one south of the airstrip, the other at Salt Rocks. There is also a less conspicuous narrow pavement east of Mary's Bay on the northeast coast. The maximum width of the two main pavements is about 50 m, and the height about 2.5 m. Similar pavements are much more widespread on both Grand Cayman and Cayman Brac.

The outer 15-20 m of the pavement has no macroscopic vegetation other than scattered patches of *Sesuvium*, *Philoxerus*, *Cenchrus* and *Sporobolus* in depressions. The inner part of the pavement is covered by the following zones, from sea to land:

- (a) a fleshy mat of *Sesuvium*;
- (b) a zone of dwarfed and prostrate shrubs, including *Conocarpus*, *Borrchia*, *Rhachicallis americana* and *Strumpfia maritima*;
- (c) a transitional zone with these dwarf shrubs and scattered *Suriana maritima*;
- (d) an inner zone of thick bushy *Suriana*, 3-4 m tall;
- (e) a hedge of dense *Coccoloba* at the inner edge of the pavement, where it passes beneath a sand or cobble beach.

This description applies to the pavement at West End Point; Sauer (1976, 5) has published a transect diagram for the same pavement somewhat further north.

The southern platform is similar except that *Laguncularia* and tall *Conocarpus* are also present and the *Coccoloba* woodland is less developed. The zonation may be compared with that described on higher and less regular coastal rocks in Antigua, where *Strumpfia* is dominant (Loveless 1960), and north Jamaica (where *Rhachicallis* is dominant (Asprey and Loveless 1958)).

5. Steep rocky coast

Bluff Limestone outcrops for a distance of 1.25 km along the coast at the east end of the island, between Snipe Point and East Point; the surface rises to a height of 6-7 m within 50 m of the shore, and the rock is deeply dissected, with many potholes 3-4 m deep. The offshore reef is narrow and gives little protection, and the lower slopes are in the splash zone. This is the kind of dissected coastal limestone described as *Soboruco* or *diente de perro* by Howard and Briggs (1953) in Cuba and by a variety of other vernacular names (*makatea*, *feo*, *champignon*) in other parts of the world; it is also the same as the Littoral Rock Pavement of Beard (1955) and Asprey and Loveless (1958).

On Little Cayman the lower splash zone is devoid of plants except for patches of *Sesuvium* in potholes. At 2-3 m above sea-level there is a prostrate scrub of dwarf shrubs, including *Conocarpus*, *Borrchia* and *Strumpfia maritima*. At rather higher levels *Suriana* becomes extensive, together with *Capparis flexuosa*, *Erithalis fruticosa*, and *Phyllanthus angustifolius*. Low *Coccoloba* becomes dominant about 30 m from the sea, forming a continuous zone 40-50 m wide, except for deeper potholes, many of which have trees of *Ficus aureus* growing in them. Further inland, away from the sea, *Bursera*, *Thespesia*, *Cordia*, *Plumeria*, *Thrinax* and *Cephalocereus* become conspicuous. Taller trees of *Bursera* are commonly deformed into a L-shape where they are emergent. This vegetation is very similar to that originally described by Beard (1955) for Barbuda, where the scrub on similar terrain consists of *Conocarpus*, *Coccoloba*, *Suriana*, *Ernodea*, *Erithalis*, *Strumpfia*, *Croton*, *Opuntia* and spherical cacti.

Sandy patches along the rocky shore at East End carry mats of *Sesuvium* and *Philoxerus*, with *Ipomoea pes-caprae*, *I. macrantha* and *Hymenocallis*, and occasional isolated trees of *Conocarpus* up to 8 m tall.

C. Mangrove communities

This category mainly comprises swamp communities dominated by mangroves. Some mangrove areas are not swampy, however, and not all Little Cayman swamps include mangroves; for convenience herbaceous swamps dominated by *Sesuvium* are included here. Little Cayman has no counterpart to the *Typha* swamps of Grand Cayman. We distinguish coastal mangroves; mangroves of coastal ponds and salt flats; inland mangroves; and herbaceous swamps.

1. Coastal mangroves

Apart from scattered beach-foot trees of *Avicennia*, *Laguncularia* and *Rhizophora* on rock and cobble headlands in Bloody Bay and Wearis Bay, coastal mangroves are restricted to a strip a few metres wide along the north shore of The Bight in South Hole Sound and on the nearby leeward shore of Owen Island. This consists of trees of *Rhizophora* and *Avicennia* 5-8 m tall; the mangrove is not sufficiently well-developed to exhibit zonation. Bare ground on the landward margin of these

mangroves is colonised by *Sesuvium*. *Batis maritima* is present but is very rare, in contrast to its luxuriant development in *Avicennia* swamp on Grand Cayman.

2. Mangroves of coastal ponds and sand flats

Extensive linear ponds are frequent between the coastal sand ridge and the limestone uplands on Little Cayman; they are shallow and rock-floored, with a variable sediment cover. The ponds vary greatly in the extent of mangroves on their shores. Some, such as those at Blossom Village and Pirate's Point, have marginal *Avicennia*, *Laguncularia* and *Conocarpus*; others, notably Tarpon Lake, have tall mature *Rhizophora* woodland (Plate 46). In the Blossom Village pond, dwarf *Avicennia* is extensive, especially at the west end, where bleached stumps indicate an even greater former extent, presumably interrupted by hurricane damage. In the Pirate's Point pond there is also a pure stand of *Acrostichum aureum* 2 m tall. This pond also contained a mat of *Ruppia maritima* in 1975, in addition to marginal mats of *Sesuvium* and *Salicornia*.

The mangrove at Tarpon Lake is the most extensive on the island, occupying an area 2.5 km long (east-west) and about 1 km wide; it has a maximum height of about 25 m. The tallest woodland consists of *Rhizophora mangle* and *Laguncularia racemosa*, with *Avicennia* and *Conocarpus* marginal on the beach-ridge side and *Avicennia* also forming part of the lake shore (Plates 47-49). There are no ferns, but on the landward side many of the trees are festooned with *Rhabdadenia biflora*. The mangrove is continuous behind the beach ridge for 2-3 km to the east of the lake, but the width of the swamp narrows to 50-200 m and the height of the tallest trees declines to only 6-8 m.

3. Inland mangroves

Mangroves are also found within some of the larger inland ponds within the Bluff Limestone. One such un-named pond (063786) at the east end is fringed with a narrow zone of *Laguncularia*, and there is a wide zone of twisted *Conocarpus* on roughly dissected limestone marginal to the pool.

The most extensive inland mangroves, however, are not directly associated with open standing water. There are three such extensive areas in the western part of the island (at 957752, 975761 and 988766). The second of these is enclosed to north and south by Bluff Limestone ridges rising to 6-13 m above sea-level, but its surface lies close to sea-level. The centre of the mangrove comprises dwarf *Rhizophora*, varying in height from 1.5-1.9 m, with lowest foliage 65-90 cm above the ground (Plate 50). These mangroves are distinguished by dense root systems and small leaves. Root densities average about 80 per sq m, with a mean root diameter 50 cm above the ground of 2.3 cm. The mean length and breadth of 50 leaves measured 10.1 and 3.8 cm, respectively, and the maxima 12.2 and 4.6 cm.

On the southern side of the dwarf *Rhizophora* there is a zone of slightly taller *Rhizophora* intermixed with *Laguncularia* and *Acrostichum*. Mean tree height in this zone is about 2 m, and the height of the lowest foliage above the ground is 0.8-1.15 m. Root density is about 55 per sq m, and mean root diameter 50 cm above the ground is 2.6 cm.

These very uniform inland *Rhizophora* swamps resemble but are much more extensive than the inland dwarf mangroves described from southern Barbuda (Stoddart, Bryan and Gibbs 1973).

Large areas of low-lying dissected Bluff Limestone in the interior of Little Cayman are also covered with dense, twisted *Conocarpus* and *Laguncularia*. The terrain is rugged, with sand-filled depressions inhabited by *Cardisoma*. Both *Erithalis* and *Strumpfia* are found in some localities marignal to these *Conocarpus* thickets.

4. Herbaceous swamp

A further type of inland marsh, also at sea-level, is found about 500 m from the sea at the east end of the island (075795), surrounded by deeply dissected Bluff Limestone ridges 2-4 m high. It consists of a thick mat of succulent *Sesuvium*, with occasional ridges and pinnacles of the underlying Bluff Limestone emerging through it. In August 1975 the whole of this marsh was waterlogged (Plate 51), and there were some small pools of standing water.

D. Classification of habitats

Johnston (1975) defined a number of "ecological formations" in the Cayman Islands, based on "major and minor plant associations, distinctive topographic features, and pertinent geologic, edaphic, and hydrologic conditions" (1975, 243). These formations were largely defined in terms of the habitat requirements of birds, both terrestrial and aquatic. The main units recognised were:

- (1) Fringing reefs and laggons.
- (2) Sand-coral beach.
- (3) Sea Grape-Almond Woodland.
- (4) Mangrove Swamp.
- (5) Pastures and cultivated areas.
- (6) Logwood Forest or scrub woodland (secondary).
- (7) Limestone Forest.
- (8) Inland lagoons and ponds.
- (9) Town and house sites.

The categories adopted have in some cases (e.g. types 6 and 9) greater relevance for Grand Cayman than for the other two islands, and in other cases, notably type 7, a single unit covers a wide variety of topographic and vegetational forms, especially on Little Cayman.

It is therefore, appropriate to conclude this chapter with a summary of the main habitats that can be recognised on Little Cayman. It is based on topography, geology and vegetation, and is intended as a framework for discussion of other aspects of the terrestrial ecology and also for consideration of conservation and management procedures. As it stands the classification is empirical and is not necessarily appropriate for the other Cayman Islands.

1. Coastal habitats

A. Sand and cobble strands.

- (a) Sand beaches with *Suriana* scrub and *Coccoloba* littoral hedge and pioneer heraceous vegetation.
- (b) Cobble beaches with *Coccoloba* littoral hedge.
- (c) Littoral woodland of coastal sand flats (almost entirely cleared).
- (d) Strand scrub, secondary scrub, and cleared and cultivated land of coastal sand flats.

B. Rocky shores.

- (a) Dwarf scrub of horizontal Ironshore pavements.
- (b) Dwarf scrub of coastal bluffs and cliffs.

C. Marine mangroves.

- (a) *Rhizophora* and *Avicennia* coastal fringes.

2. Non-marine Mangroves

A. Mangrove woodland.

- (a) Tall *Rhizophora* woodland (Tarpon Lake).
- (b) Low *Rhizophora* woodland on salt-pond margins.
- (c) *Conocarpus* and herbaceous vegetation of rock flats round salt ponds (*Sesuvium* sward, *Salicornia* sward, *Acrostichum* clumps).

B. Mangrove scrub.

- (a) Dwarf inland *Rhizophora* scrub in enclosed basins.
- (b) *Conocarpus-Laguncularia* scrub of low dissected interior Bluff Limestone.

C. Herbaceous marsh.

- (a) *Sesuvium* marsh of interior basins in Bluff Limestone.

3. Interior limestone areas

A. Bluff Limestone.

- (a) Dry Evergreen Thicket on dissected limestone ridges.
- (b) Evergreen Bushland on low dissected limestone.
- (c) See category 2.B.b.

B. Ironshore Formation.

- (a) Dry Evergreen Forest on low undissected Marl Facies.
- (b) Dry Evergreen Woodland on gentle slopes of low undissected Marl Facies ridges.
- (c) Evergreen Bushland on low undissected Marl Facies (disturbed?).

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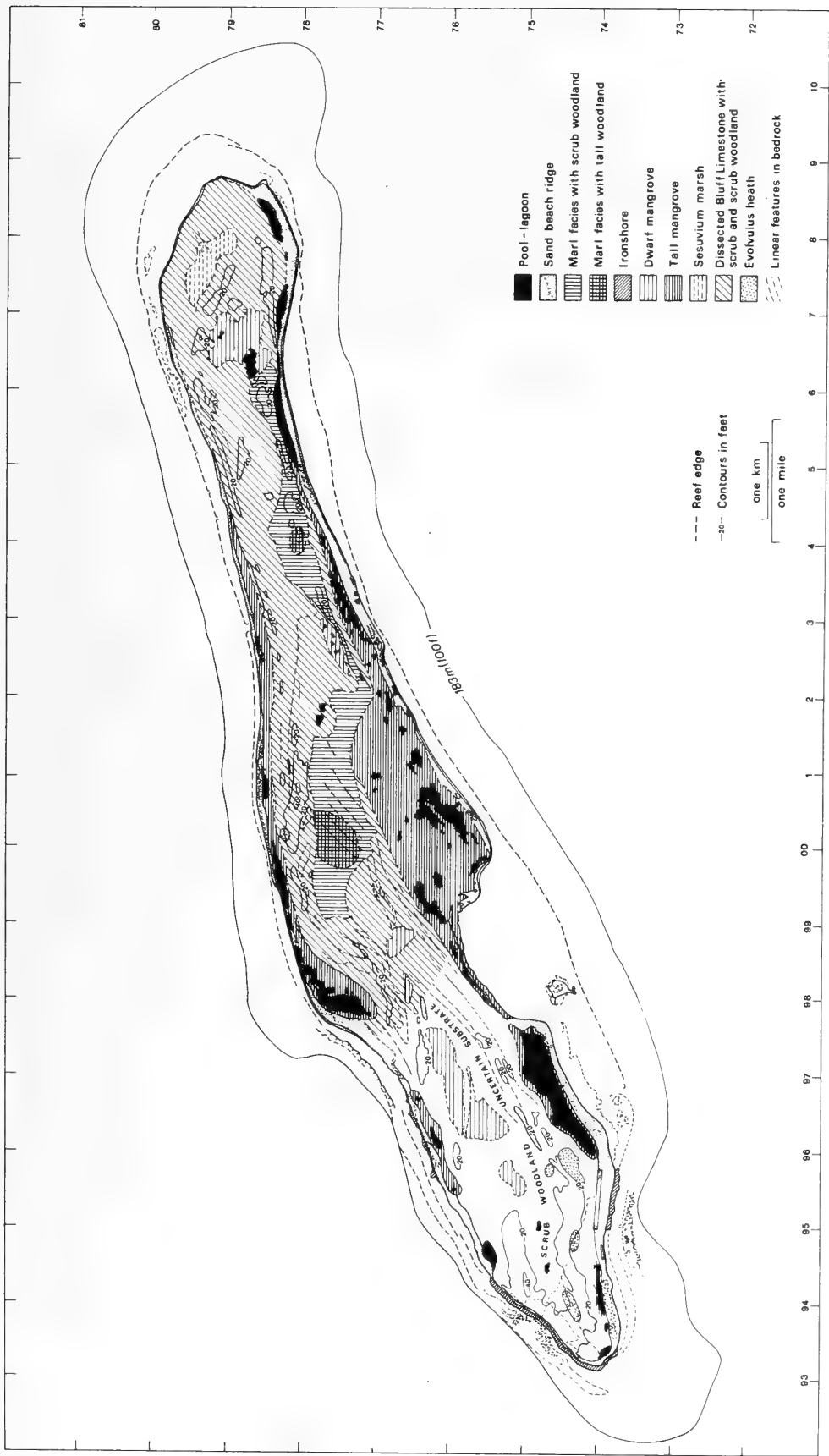


Figure 21. Habitats and geology of Little Cayman



Plate 37. Dry evergreen forest south of Sparrowhawk Hill; note the human figure in the centre of the picture (6003 1775)



Plate 38. Dry evergreen thicket on Sparrowhawk Hill (6004 1780)



Plate 39. Dry evergreen woodland inland from Jackson's Bay
(5977 1768)



Plate 40. Open dry evergreen thicket on the northern slopes of
Sparrowhawk Hill (6003 1781)



Plate 41. *Acrostichum aureum* in limestone solution holes north of Blossom Village (5953 1750)



Plate 42. Wind-sheared coastal hedge of *Coccoloba uvifera*, Owen Island



Plate 43. Pioneer *Hymenocallis littorea* and other herbaceous pioneers at Sandy Point



Plate 44. Decapitated coconuts on the coastal beach ridge near West Point



Plate 45. Coconut plantation with many dead trees on Owen Island



Plate 46. Low *Rhizophora* in the coastal lagoon east of Diggary's Point (6030 1773)



Plate 47. Tall *Avicennia* woodland in Tarpon Lake



Plate 48. Tall *Rhizophora* woodland in Tarpon Lake



Plate 49. Interior of tall *Rhizophora* woodland at Tarpon Lake



Plate 50. Dwarf inland *Rhizophora* in an interior depression
(5975 1761)



Plate 51. Inland *Sesuvium* marsh with open pools at the east end of the island (6074 1795)

7. CHECKLIST OF THE PLANTS OF LITTLE CAYMAN

G.R. Proctor

Note: Names in Prestige Elite/*Light Italic* e.g. Item 2 are taxa added to the Little Cayman list during the Royal Society - Cayman Islands Government Expedition in August, 1975. Names preceded by an asterisk (*) represent taxa known only from Little Cayman in the Cayman Islands. Two asterisks (**) indicate species endemic to Little Cayman. Names enclosed by square brackets [...] represent plants not indigenous to Little Cayman. Collection-numbers preceded by a 'K' designate plants collected by Wilfred Kings; those preceded by a 'P' represent collections of George R. Proctor. The plant families are listed in the same order as in Proctor's unpublished "Flora of the Cayman Islands".

1. POLYPODIACEAE

Acrostichum aureum L. K-LC 54; P-28090

2. CYCADACEAE

Zamia media var. *commeliniana* Schuster P-35122

3. HYDROCHARITACEAE

Thalassia testudinum König K-LC 62-a, LC 98, LC 121; P-28109

4. RUPPIACEAE

Ruppia maritima L. ? (immature) P-35182.

5. ZOSTERACEA

Halodule wrightii Aschers. K-LC 120-a; P-28108

Syringodium filiforme Kütz. K-LC 120, MA 93-a; P-28107

6. CYPERACEAE

- Abildgaardia ovata* (Burm.f.) Kral P-28190, 35133
Cyperus kingsii C.D.Adams P-35098, 35205
Cyperus ligularis L. P-28072
Cyperus planifolius L.C.Rich. K-LC 3, LC 92, LC 101; P-28071
Fimbristylis cymosa R.Br. P-35177
Fimbristylis ferruginea (L.) Vahl K-LC 74
Remirea maritima Aubl. K-LC 81; P-35084
Scleria lithosperma (L.) Sw. K-LC 58; P-28120

7. GRAMINEAE

- [*Andropogon pertusus* (L.) Willd.] P-35200
Antheophora hermaphrodita (L.) Ktze. P-28156
Cenchrus incertus M.A.Curtis (*C. pauciflorus* Benth.) P-28157
Cenchrus echinatus L. P-28153
Cenchrus tribuloides L. K-LC 107
Chloris petraea Sw. K-LC 103; P-28083
Digitaria horizontalis Willd. P-28152
[*Eleusine indica* (L.) Gaertn.] P-28154
Eragrostis ciliaris (L.) R.Br. P-28155
[*Eragrostis tenella* (L.) Beauv.] P-28192
Lasiacis divaricata (L.) Hitchc. K-LC 94
[*Panicum maximum* Jacq.] P-28151
Paspalum blodgettii Chapm. P-28082
Paspalum distichum L. (*P. vaginatum* Sw.) K-LC 84-a; P-28067
[*Rhynchelytrum repens* (Willd.) C.E. Hubb.] P-28143
Spartina patens (Ait.) Muhl. K-LC 20; P-28194
Sporobolus virginicus (L.) Kunth K-LC 84; P-28081
Stenotaphrum secundatum (Walt.) Ktze. K-LC 44
Trichachne insularis (L.) Nees K-LC 97; P-28158

8. BROMELIACEAE

- Tillandsia balbisiana* Schult.f. K-LC 2, LC 113, LC 115; P-28131
**Tillandsia bulbosa* Hook. K-LC 114
**Tillandsia circinnata* Schlecht. K-LC 114-a; P-28133
**Tillandsia fasciculata* Sw. var. *clavispica* Mez P-35171
Tillandsia flexuosa Sw. K-LC 116; P-28132
Tillandsia recurvata L. K-LC 76; P-28134
Tillandsia utriculata L. K-LC 52; P-35079, 35192

9. PALMAE

- Coccothrinax jamaicensis* R.W.Read P-35082
Thrinax radiata Lodd. K-LC 47, LC 104

10. LILIACEAE

- Agave sobolifera* Salm-Dyck P-sight record (plants sterile)
[*Agave* sp. indet.] P-sight record (plants sterile): escaped from cultivation.

- [*Crinum zeylanicum* (L.) L.] P-sight record: relic of cultivation.
Hymenocallis latifolia (Mill.) M.J.Roem. K-LC 105; P-28079
 [Sansevieria *hyacinthoides* (L.) Druce] P-sight record: escaped
 from cultivation.

11. ORCHIDACEAE

- ***Epidendrum kingsii* C.D.Adams K-LC 117-a (type)
Schomburgkia brysiana Lemaire var. *minor* (Hook.f.) H.G.Jones
 K-LC 7

12. CANELLACEAE

- Canella winterana* (L.) Gaertn. K-LC 15; P-28117, 28177

13. LAURACEAE

- Cassytha filiformis* L. K-LC 29, LC 82, LC 85; P-28080

14. ULMACEAE

- Celtis iguanaea* (Jacq.) Sarg. P-28027
Trema lamarckiana (R. & S.) Blume K-LC 79

15. MORACEAE

- Ficus aurea* Nutt. K-LC 87, LC 88; P-28042
Ficus citrifolia Mill. K-LC 88-a

16. PHYTOLACCACEAE

- Rivina humilis* L. P-28036

17. NYCTAGINACEAE

- Boerhavia erecta* L. P-28167
Boerhavia diffusa L. K-LC 59; P-28166
Guapira discolor (Spreng.) Little K-LC 37; P-28037, 28061
Pisonia aculeata L. P-35078

18. CACTACEAE

- Cephalocereus swartzii* (Griseb.) Brit. & Rose P-35074
Harrisia gracilis (Mill.) Britton P-35118
 [Opuntia *cochenillifer* (L.) Mill.] P-35195
Opuntia dillenii (Ker-Gawl.) Haw. P-35097

19. PORTULACACEAE

- Portulaca oleracea* L. K-LC 24; P-28169, 28170
Portulaca phaeosperma Urban P-28176, 35088, 35140
Portulaca tuberculata Leon P-28191, 35089
 **Sesuvium microphyllum* Willd. P-28056

Sesuvium portulacastrum L. P-28066
 [*Talinum triangulare* (Jacq.) Willd.] P-35142

20. BASELLACEAE

Anredera leptostachys (Moq.) van Steenis P-28147

21. CHENOPODIACEAE

**Atriplex pentandra* (Jacq.) Standley (Reported by Jonathan Sauer)
 **Salicornia bigelovii* Torr. K-LC 117; P-35072

22. AMARANTHACEAE

Philoxerus vermicularis (L.) Beauv. K-LC 27; P-28181

23. BATIDACEAE

Batis maritima L. K-LC 118, LC 119

24. POLYGONACEAE

Coccoloba uvifera (L.) L. P-28051, 28099

25. TILIACEAE

Corchorus siliquosus L. P-28160

26. STERCULIACEAE

Helicteres jamaicensis Jacq. K-LC 32; P-28034
Melochia tomentosa L. K-LC 95; P-28141
Waltheria indica L. P-28084

27. MALVACEAE

Gossypium hirsutum L. K-LC 10, LC 11; P-28150
Hibiscus tiliaceus L. K-LC 71; P-35110
Malvaviscus arboreus Cav. var. *cubensis* Schlecht. P-35103
Sida stipularis Cav. P-28164
Thespesia populnea (L.) Soland. K-LC 70; P-28076; Sauer 4174

28. FLACOURTIACEAE

Zuelania quidonia (Sw.) Britton & Millsp. P-35213

29. TURNERACEAE

**Turnera diffusa* Willd. P-28113, 35127
Turnera ulmifolia L. K-LC 102; P-28049

30. PASSIFLORACEAE

- Passiflora cupraea* L. P-35113
Passiflora suberosa L. P-28057

31. CARICACEAE

- Carica papaya* L. K-LC 80

32. CAPPARIDACEAE

- Capparis cynophallophora* L. P-35214, 35218
Capparis flexuosa (L.) L. K-LC 109; P-28044

33. CRUCIFERAE

- Cakile lanceolata* (Willd.) O.E.Schulz K-LC 91

34. SAPOTACEAE

- Bumelia glomerata* Griseb. P-28089
Bumelia salicifolia (L.) Sw. P-28115, 35173, 35217
Manilkara zapota (L.) van Royen P-28148

35. THEOPHRASTACEAE

- Jacquinia berterii* Spreng. P-28105, 28184, 28189, 35077

36. CRASSULACEAE

- [*Bryophyllum pinnatum* (Lam.) Oken] P-28178

37. CHRYSOBALANACEAE

- Chrysobalanus icaco* L. P-28144

38. LEGUMINOSAE (Papilionoideae or Faboideae)

- Abrus precatorius* L. P-28065
Canavalia rosea (Sw.) DC. K-LC 23; P-28085
Crotalaria verrucosa L. P-28064
Dalbergia ecastaphyllum (L.) Taub. K-LC 89, LC 90; P-35208
[*Indigofera tinctoria* L.] P-35196
Rhynchosia minima (L.) DC. P-28161
Stylosanthes hamata (L.) Taub. K-LC 75; P-28062
Vigna luteola (Jacq.) Benth. K-LC 73

LEGUMINOSAE (Caesalpinioideae)

- Bauhinia divaricata* L. K-LC 106; P-28040
Caesalpinia bonduc (L.) Roxb. K-LC 46; P-28032
Caesalpinia crista L. P-28063, 35109, 35124

LEGUMINOSAE (Mimosoideae)

Calliandra cubensis (Macbr.) Leon P-35189

39. MYRTACEAE

Calypttranthes pallens Griseb. K-LC 16; P-28127

**Calypttranthes zuzygium* (L.) Sw. ? (identity in doubt) K-LC 68

Eugenia axillaris (Sw.) Willd. P-35099, 35167, 35204

Myrcianthes fragrans (Sw.) McVaugh K-LC 65; P-28092, 35076

40 COMBRETACEAE

Conocarpus erecta L. var. *erecta* K-LC 21; P-28103

var. *sericea* DC. K-LC 49; P-28174

Laguncularia racemosa (L.) Gaertn. K-LC 29, LC 30; P-28075, 28173

[*Terminalia catappa* L.] K-LC 55; P-35094

41. RHIZOPHORACEAE

Rhizophora mangle L. K-LC 31, LC 31-a

42. OLACACEAE

Schoepfia chrysophylloides (A.Rich.) Planch. P-28121

Ximenia americana L. P-28086, 35091

43. LORANTHACEAE

**Dendropemon caymanensis* Proctor P-35215

Phoradendron quadrangulare (Kunth) Kr. & Urb. P-35194 (Other numbers cited under this name probably all pertain to the following species.)

Phoradendron trinervium (Lam.) Griseb., sens. lat. (but not the same as Jamaican plants cited under this name.) K-LC 36 ?, LC 43 ?; P-28122, 28185, 35075, 35100

44. CELASTRACEAE

Crossopetalum rhacoma Crantz P-28098

Gyminda latifolia (Sw.) Urban P-28093, 35135

**Maytenus buxifolia* (A.Rich.) Griseb. K-LC 67; P-28091

Schaefferia frutescens Jacq. P-28182

45. BUXACEAE

**Buxus bahamensis* Baker P-28138, 35136

46. EUPHORBIACEAE

Adelia ricinella L. P-28119

Argythamnia proctorii Ingram P-28123, 35081

- Ateramnus lucidus* (Sw.) Rothm. P-35188
Bernardia dichotoma (Willd.) Muell.Arg. P-35104
Chamaesyce blodgettii (Engelm.) Small P-28145, 28168
 ***Chamaesyce bruntii* Proctor P-28146 (type), 35083
 ***C. bruntii* var. *pubescens* Proctor P-35090 (type)
Chamaesyce hirta (L.) Millsp. P-35181
Chamaesyce hypericifolia (L.) Millsp. P-35185
Chamaesyce mesembrianthemifolia (Jacq.) Dugand K-LC 93; P-28070;
 Sauer 4166
Chamaesyce ophthalmica (Pers.) Burch P-35138
Croton linearis Jacq. K-LC 9; P-28029
Croton lucidus L. K-LC 13, LC 53; P-28139
Croton nitens Sw. P-28030, 28110
Croton rosmarinoides Millsp. P-28137, 35073
Euphorbia trichotoma Kunth P-35178
Hippomane mancinella L. P-28100
Phyllanthus amarus Schum. & Thonn. P-35198
Phyllanthus angustifolius (Sw.) Sw. P-28052, 28188, 35085, 35086,
 35191; Sauer 4171
Phyllanthus mocinianus Baill. P-35145
Phyllanthus nutans Sw. ssp. *nutans* P-28039
 ssp. *grisebachianus* (Muell.Arg.) Webster
 K-LC 42 (P-35111, 35209, 35212 not yet det.
 to ssp.)
Picrodendron baccatum (L.) Kr. & Urb. K-LC 77; P-28038
Poinsettia cyathophora (Murray) Kl. & Gke. K-LC 51
 [Ricin *communis* L.] K-LC 108
Savia erythroxyloides Griseb. K-LC 64; P-28094, 35108

47. RHAMNACEAE

- Colubrina asiatica* (L.) Brongn. P-28159; Sauer 4172
Colubrina cubensis (Jacq.) Brongn. P-35186
Colubrina elliptica (Sw.) Briz. & Stern P-28114

48. VITIDACEAE

- Cissus microcarpa* Vahl P-35117
Cissus sicyoides L. P-35221
Cissus trifoliata L. K-LC 99; P-28031

49. STYLOBASIACEAE

- Suriana maritima* L. K-LC 85; P-28077

50. SAPINDACEAE

- Allophylus cominia* (L.) Sw. var. *caymanensis* Proctor P-35219
Cardiospermum corindum L. P-28125, 35096, 35180
Dodonaea viscosa (L.) Jacq. K-LC 69; P-28078
Hypelate trifoliata Sw. P-28102, 35139

51. BURSERACEAE

Bursera simaruba (L.) Sarg. P-28046

52. ANACARDIACEAE

Comocladia dentata Jacq. P-35183

Metopium toxiferum (L.) Kr. & Urb. P-28128

53. SIMAROUBACEAE

Alvaradoa amorphoides Liebm. P-35093

54. RUTACEAE

Amyris elemifera L. P-28101

Fagara flava (Vahl) Kr. & Urb. P-35115

Fagara spinosa (L.) Sw. P-35105, 35216

55. MELIACEAE

Swietenia mahagoni Jacq. P-28179

Trichilia glabra L. P-28028, 35095, 35101

56. ZYGOPHYLLACEAE

Tribulus cistoides L. K-LC 57; P-28172

57. ERYTHROXYLACEAE

Erythroxylum aerolatum L. P-35092

Erythroxylum rotundifolium Lunan K-LC 63; P-28106, 28187

58. POLYGALACEAE

**Polygala propinqua* (Britton) Blake P-28104, 35087

59. APOCYNACEAE

[*Catharanthus roseus* (L.) G. Don] P-35197

Echites umbellata Jacq. K-LC 1, LC 86

Plumeria obtusa L. K-LC 8; P-28043

Rhabdadenia biflora (Jacq.) Muell. Arg. K-LC 34; P-35116

60. ASCLEPIADACEAE

Cynanchum picardae (Schltr.) Jimenez P-35125

Sarcostemma clausum (Jacq.) Schult. P-35121

61. SOLANACEAE

Solanum bahamense L. K-LC 33

62. CONVOLVULACEAE

- **Dichondra repens* J.R. & G.Forst. P-28193
 **Evolvulus arbuscula* Poir. K-LC 35, LC 76-a; P-28087, 28130
Ipomoea acuminata (Vahl) R. & S. K-LC 19; P-35112
Ipomoea macrantha R. & S. K-LC 45; P-28045
Ipomoea pes-caprae ssp. *brasiliensis* (L.) Ooststr. K-LC 18; P-28165
Ipomoea stolonifera (Cyrillo) J.F. Gmel. P-28053
Ipomoea triloba L. P-35141, 35184

63. BORAGINACEAE

- Bourreria venosa* (Miers) Stearn P-28149, 35144
Cordia brownei (Friesen) I.M.Johnst. P-28142, 35126
Cordia gerascanthus L. P-28126
Cordia sebestena L. var. *caymanensis* (Urb.) Proctor K-LC 4;
 P-28047
Heliotropium angiospermum Murray K-LC 41; P-28058
Heliotropium humifusum Kunth K-LC 48, LC 78; P-28129, 35137
Mallotonia gnaphalodes (L.) Britton K-LC 56; P-28171
Tournefortia volubilis L. K-LC 12; P-28112, 35102

64. VERBENACEAE

- Citharexylum fruticosum* L. P-28135
Clerodendrum aculeatum (L.) Schlecht. P-28111
Lantana aculeata L. P-35179
Lantana camara L. P-28035
Lantana involucrata L. K-LC 38; P-28059
Lippia nodiflora (L.) Michx. K-LC 72
Staphytarpheta jamaicensis (L.) Vahl P-28048

65. AVICENNIACEAE

- Avicennia germinans* (L.) L. K-LC 28; P-28073

66. LABIATAE

- Ocimum micranthum* Willd. K-LC 6
Salvia occidentalis Sw. K-LC 61

67. OLEACEAE

- ***Chionanthus* sp. nov. ined. P-28116, 28183
Forestiera segregata (Jacq.) Kr. & Urb. P-35134

68. MYOPORACEAE

- Bontia daphnoides* L. P-28175

69. BIGNONIACEAE

- Tabebuia heterophylla* (DC.) Britton K-LC 14; P-28080

70. GOODENIACEAE

Scaevola plumieri (L.) Vahl K-LC 66; P-28025

71. RUBIACEAE

Antirhea lucida (Sw.) Hook.f. P-35080, 35211
Borreria laevis (Lam.) Griseb. P-35199
Catesbaea parviflora Sw. P-35107
Chiococca alba (L.) Hitchc. P-28118
Erithalis fruticosa L. K-LC 100; P-28097
Ernodea littoralis Sw. K-LC 17; P-28096
Exostema caribaeum (Jacq.) Schult. P-28140
Guettarda elliptica Sw. P-28136, 35106, 35114, 35119
Hamelia cupraea Griseb. P-35123
[*Morinda citrifolia* L.] K-LC 112
Randia aculeata L. P-28041, 35120, 35172
Rhachicallis americana (Jacq.) Ktze. P-28055
Strumpfia maritima Jacq. P-28095; Sauer 4190

72. COMPOSITAE

Ambrosia hispida Pursh K-LC 25, LC 26; P-28068
Baccharis dioica Vahl P-35190
Bidens pilosa var. *radiata* Sch.Bip. K-LC 60
Borrchia arborescens (L.) DC. K-LC 40; P-28026
Conyza canadensis (L.) Cronquist P-28162
Eupatorium villosum Sw. P-35143
Melanthera aspera (Jacq.) L.C.Rich. K-LC 22; P-28050, 28054
Pectis caymanensis (Urb.) Rydb. P-28186, 35193
Salmea petrobioides Griseb. P-35222
Spilanthes urens Jacq. P-28069
Vernonia divaricata Sw. P-28124, 35146
Wedelia trilobata (L.) Hitchc. K-LC 50

8. THE TERRESTRIAL FAUNA (EXCLUDING BIRDS AND INSECTS) OF LITTLE CAYMAN

M.V. Hounsome

Abstract

Terrestrial animals were collected and observed by members of the Royal Society and Cayman Islands Government expedition to Little Cayman in July and August of 1975. A fauna list has been compiled and analysed with reference to the various habitat types. The sand beach ridge, with its associated human disturbance, and the marl facies with tall scrubland are by far the richest habitats, the latter being worthy of the special attention of conservationists.

Introduction

Stoddart (chapter 6) has described the terrestrial habitats of Little Cayman, which may be summarised as follows:-

1. Pool Lagoon
2. Sandbeach Ridge
3. Marl Facies with scrub
4. Marl Facies with tall scrub
5. Dwarf Mangrove
6. Tall Mangrove
7. *Sesuvium* Marsh
8. Dissected Bluff
9. *Evolvulus* Heath
10. Ironshore

The Pool Lagoon, *Sesuvium* Marsh and Ironshore and largely aquatic habitats were not intensively sampled for terrestrial animals, but the remaining seven habitat types were visited and the animals collected or recorded. The invertebrates were preserved in alcohol and the vertebrates were killed by an excess of narcotic ('Nembutal') and subsequently preserved in alcohol. The identifications were carried out, as far as possible at Manchester University, but many specimens

had to be passed on to the British Museum (Nat. Hist.) for identification or confirmation; the pseudoscorpions and one species of crab (*Sesarma angustipes* Dana) had to be sent to Austria and the United States respectively for expert opinions. The specimens have all been retained by the Manchester Museum, or have been deposited in the British Museum (Natural History).

Methods

Collections of animals were made on daily visits to the various localities on Little Cayman (see appendix). Preliminary sorting and preservation was carried out after each visit. A record of grid references was made and likely sites identified on the map. Most of the collecting visits were made together with other members of the expedition, so that a wide variety of sites were covered. Notes of sightings in the field were made so as to supplement the records from collected specimens; this was especially useful for the reptiles and the most common molluscs.

Results

A complete list of the species found is given in table 7. Our knowledge of the molluscs of Little Cayman has been summarised by Clench (1964), and that of the amphibians and reptiles by Williams (1964, 1969) and Schwartz & Thomas (1975), but none of the other groups has received such a systematic treatment. Of the previously recorded reptiles, the gekko *Aristelliger praesignis* Boulenger, the snake *Tropidophis caymanensis parkeri* Grant and the crocodile *Crocodilus acutus* Cuvier were not seen in 1975. Of the molluscs the following five species on Clench's list were not found in 1975: *Acadia lewisi* Pilsbry, *Gastrocopta rupicola marginalba* (Pfeiffer), *G. pellucida* (Pfeiffer), *Pupoides albilabris* (Adams), and *Ceciloides iota* (Adams). On the other hand, three species of gastropod were added to Clench's list, viz. *Drepanotrema lucidum* (Pfeiffer), *Geomelania (Merrilliana) alemon* Pilsbry, and *Lamellaxis micrus* (d'Orbigny).

Discussion

Of the eighty one species recorded fifty six (69%) were present in only one of the seven habitat types, and seventy two (89%) were present in only one or two habitats. There were only five (6%) species (Mollusca: *Helicina fasciata* and *Cerion pannosum*; Amphibia: *Osteopilus septentrionalis* Reptilia: *Anolis maynardi* and *A. sagrei*) recorded from four or more habitats (appendix 2). This situation can be interpreted as meaning that most of the species are habitat specific, although insufficient sampling could produce similar figures, and negative records do not necessarily imply the absence of a species from a certain habitat. Several further visits would be needed before firm conclusions as to habitat specificity could be drawn.

From table 8 it may be seen that only three of the habitat types supplied more than ten different species. Of these, the dissected

Bluff was by far the most extensive and was consequently the most sampled. The number of recorded species per site (1.83) in this habitat type was only average, and it is possible that few further species remain to be discovered. By contrast, the two other types (the sandbeach ridge and the tall scrub) show a far greater diversity and probably harbour many more species than were recorded in 1975 (fig.23).

The sandbeach ridge has been subject to much human disturbance in the form of house and road building, and coconut planting. The high diversity of the fauna can in large measure be attributed to this disruption, together with the introduction of species such as the rat (*Rattus rattus*) and the black widow spider (*Latrodectus mactans*). Further development of the sandbeach ridge would probably not greatly affect its faunistic nature, which may be regarded as artificial and of little intrinsic interest. This situation may be contrasted with that of the 'central forest', or marl facies with tall scrub, where the number of species is high for such faunistical impoverished island, and where sixteen species are found which do not occur in the other habitats. This area may be regarded as unique and of great biological value. It is to be hoped that this will be taken into account in any proposed developments on the island. In many ways Little Cayman may be regarded as an impoverished outpost of Cayman Brac, but this central forest area is of particular importance, and plans for its conservation should be made before any developments get under way.

The other important conservation area is the *Evolvulus* heath centred around grid 958746 north east of the airstrip. This is because of the unique occurrence of the snail *Cerion nanus* rather than the general faunistic importance of the area. This snail must be one of the rarest animals in the world, with only 87 individuals found in 1975, and a world distribution covering an area of about 600 sq. metres on the western end of Little Cayman (Hounscome & Askew, 1979). It is found only on the plant *Evolvulus arbuscula* which is not found on the other Cayman islands but which grows on Jamaica, Hispaniola, the Cuban Keys and the Bahamas. *Cerion nanus* is vulnerable to any developments in its area of Little Cayman and particular efforts should be made for its conservation. In the last resort, transporting the population to another island with *Evolvulus arbuscula* might have to be carried out, even though such a translocation is unlikely to be successful.

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Table 7. Terrestrial Fauna of Little Cayman, July and August 1975
(excluding birds and insects)

(Numbers refer to habitat type)

	Mollusca	
	Gastropoda	
	Prosobranchia	
	Mesogastropoda	
1	Cerithiidae	<i>Cerithidea costata</i> Da Costa
2,4,6,8	Pulmonata Helicinidae	<i>Helicina fasciata substriata</i> Grey
8		<i>Lucidella caymanensis</i> Pilsbry
3,6,8	Chondropomidae	<i>Chondropoma caymanbracense</i> <i>parvicaymanense</i> Pilsbry
8	Truncatellidae	<i>Geomelania (Merrilliana)</i> <i>alemon</i> Pilsbry
4,8	Planorbidae	<i>Drepanotrema lucidum</i> (Pfeiffer)
	Succineidae	<i>Succinea latior</i> Adams (GRAND CAYMAN)
4,8	Strobilopsidae	<i>Strobilops (Discostrobilops)</i> <i>hubbardi</i> (Brown)
	Subulinidae	<i>Lamellaxis micrus</i> (d'Orbigny)
4	Oleacinidae	<i>Varicella caymanensis</i> Pilsbry
4		<i>Melaniella gracillima</i> (Pfeiffer)
		? <i>Spiraxis</i> sp.
4	Sagdididae	<i>Lacteoluna caymanbracensis</i> Pilsbry
4,6,8		<i>Proserpinula lewisi</i> Pilsbry
2,3,4,5,6,8,9	Cerionidae	<i>Cerion pannosum</i> (Maynard)
9		<i>Cerion nanus</i> (Maynard)
9	Urocoptidae	<i>Microceramus caymanensis</i> Pilsbry
4		<i>Brachypodella caymanensis</i> Pilsbry
3,8	Fruticolidae	<i>Hemitrochus streator</i> Pilsbry
	Arthropoda	
	Chilipoda	
	Epimorpha	
	Geophilomorpha	
8	Geophilidae	<i>Leptophilus caribeanus</i> Chamberlin
	Scolopendromorpha	
4	Scolopendridae	<i>Cormocephalus cf impressus</i>
4	Cryptopidae	<i>Cryptops</i> sp.
	Anamorpha	
	Scutigeromorpha	
2	Scutigeridae	? <i>Pselliophora</i> sp.

	Diplopoda		
	Chilognatha		
	Spirobolida		
3,4	Rhinocricidae	<i>Eurhynocricus cf fissus</i>	
		Verhoeff	
	Crustacea		
	Malacostraca		
	Peracarida		
	Isopoda		
8	Orchestiadae	<i>Orchesta</i> sp.	
	Amphipoda		
2	Ligiidae	<i>Ligia baudiniana</i> (Milne Edwards)	
4	Oniscidae	<i>Philoscia brevicornis</i> Budde Lunde	
8		<i>Philoscia</i> sp.	
		gen. incertum	
	Eucarida		
	Decapoda		
	Reptantia		
2	Geocarcinidae	<i>Cardisoma guanhumi</i> Latreille	
2,4	Coenobitidae	<i>Coenobita clypeatus</i> (Herbst)	
1,2	Grapsidae	<i>Sesarma angustipes</i> Dana	
2,6,8	Ocypodidae	<i>Uca speciosa</i> (Ives)	
2		<i>Ocypode quadrata</i> (Fabricus)	
	Arachnida		
	Scorpiones		
3,4	Diplocentridae	<i>Diplocentrus scaber</i> Pocock	
2	Buthidae	<i>Centuroides nitidus</i> (Thor.)	
	Pseudoscorpiones		
8	Neobisiidae	<i>Ideobisum simile</i> (Balzan)	
8	Olpiidae	<i>Pachyolpium furculiferum</i> (Balzan)	
8		<i>Apolpium longidigitatum</i> (Ellingsen)	
4	Sternophoridae	<i>Garyops depressa</i> Banks	
4	Chernetidae	<i>Byrsochernes caribicus</i> Beier	
	Amblypygi		
2,4	Tarantulidae	<i>Tarantula marginemaculata</i> Koch	
	Solifugae		
4	Ammotrechidae	? <i>Ammotrechella</i> sp.	
	Opiliones, Laniatores		
4	Phalangodidae	<i>Stygnumma spinifera</i> (Packard)	
	Araneae		
4	Dinopidae	<i>Dinopis</i> sp.	
2	Scytodidae	<i>Scytodes fusca</i> Walckenaer	
2,8	Sicaridae	<i>Sicarius</i> sp.	
2	Pholcidae	<i>Pholcus phalangoides</i> (Fuesslin)	
2,8		<i>Physocyclus globosus</i> Taczanowski	
4		gen. incertum	

2,8	Gnaphosidae	<i>Drassodes</i> or <i>Haplodrassus</i> sp.
2	Clubionidae	<i>Clubiona</i> sp.
8		gen. incertum
8	Thomisidae	<i>Xysticus</i> sp.
8		<i>Misumenops</i> sp.
2,8		<i>Misumena</i> sp.
2		gen. incertum
4	Salticidae	<i>Habrocrestum splendens</i> Emerton
8		<i>Marpissa</i> or <i>Hycitia</i> sp.
4		gen. incertum
8	Lycosidae	<i>Lycosa</i> sp.
2	Agelenidae	<i>Agelenopsis</i> or <i>Tegenaria</i> sp.
2		<i>Agelena</i> or <i>Agelenopsis</i> sp.
2		gen. incertum
2	Zodariidae	<i>Storena</i> sp.
2	Theridiidae	<i>Theridion</i> sp.
2,8		<i>Latrodectus mactans</i> (Fabricus)
2		<i>Spinarthus flavidus</i> Hentz
4	Ctenizidae	<i>Bothriocyrtum</i> or <i>Ummidia</i> sp.
	Araneidae	<i>Argiope argentata</i> (Fabricus)
		(CAYMAN BRAC)
2,8		<i>Araneus</i> sp.
8		<i>Meta</i> sp.
		<i>Cyclosa</i> sp.
2,4,6		<i>Nephilia clavipes</i> (Lin)
8		<i>Gasteracantha cancriformis</i>
		(Lin)
	Chordata	
	Amphibia	
	Salienta	
	Procoela	
1,2,8,9	Hylidae	<i>Osteopilus septentrionalis</i>
		(Duméril & Bibron)
	Reptilia	
	Squamata	
	Sauria	
2,4	Gekkonidae	<i>Sphaerodactylus argivus</i>
		<i>bartschi</i> Cochran
2,3,4,5,6,8,9	Iguanidae	<i>Anolis maynardi</i> Garman
2,3,4,5,6,8,9		<i>Anolis sagrei sagrei</i> Duméril
		& Bibron
		<i>Anolis sagrei luteosignifer</i>
		Garman (CAYMAN BRAC)
2,3,9		<i>Cyclura nubila caymanensis</i>
		Barbour & Noble
2		<i>Leiocephalus carinatus granti</i>
		Rabb
4	Anguidae	<i>Diploglossus cruscus</i>
		<i>maculatus</i> Garman
	Serpentes	
2	Colubridae	<i>Alsophis cantherigerus ruttii</i>
		Grant

		<i>Alsophis cantherigerus</i>
		<i>fascicauda</i> Garman (CAYMAN BRAC)
	Mammalia	
	Theria	
	Chiroptera, Microchiroptera	
2	Phyllastomidae	<i>Macrotus waterhousi minor</i> Gundlach
	Molossidae	<i>Molossus tropidorhynchus</i> Gray (GRAND CAYMAN)
	Rodentia, Myomorpha	
2	Muridae	<i>Rattus rattus</i> L.

Table 8. Species Diversity in each of the habitat types

<u>Habitat</u>	<u>No of species</u>	<u>No of sample sites</u>	<u>No of species per sample site</u>
2. Sandbeach ridge	37	6	6.17
3. Marl with scrub	9	5	1.80
4. Marl with tall scrub	32	3	10.67
5. Dwarf Mangrove	3	1	3.00
6. Tall Mangrove	6	3	2.00
8. Dissected bluff	33	18	1.83
9. Evolvulus heath	6	4	1.50

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Appendix. Grid references to collecting localities

1. Pool Lagoon	005761, 000783
2. Sandbeach Ridge	943739, 951757, 963739, 977771, 020767, 045778
3. Marl Facies with Scrub	045780, 005775, 061785, 062785, 062786
4. Marl Facies with Tall Scrub	002775, 003775, 041778
5. Dwarf Mangrove	965763
6. Tall Mangrove	960740, 985758, 042789
7. <i>Sesuvium</i> Marsh	078794
8. Dissected Bluff	943740, 94997555, 961743, 974763, 974766, 975755, 978754, 001778, 001780, 008779 028781, 041788, 04457842, 045785, 075798, 07757825, 078797, 087792
9. <i>Evolvulus</i> Heath	95877460, 959743, 960743, 958743

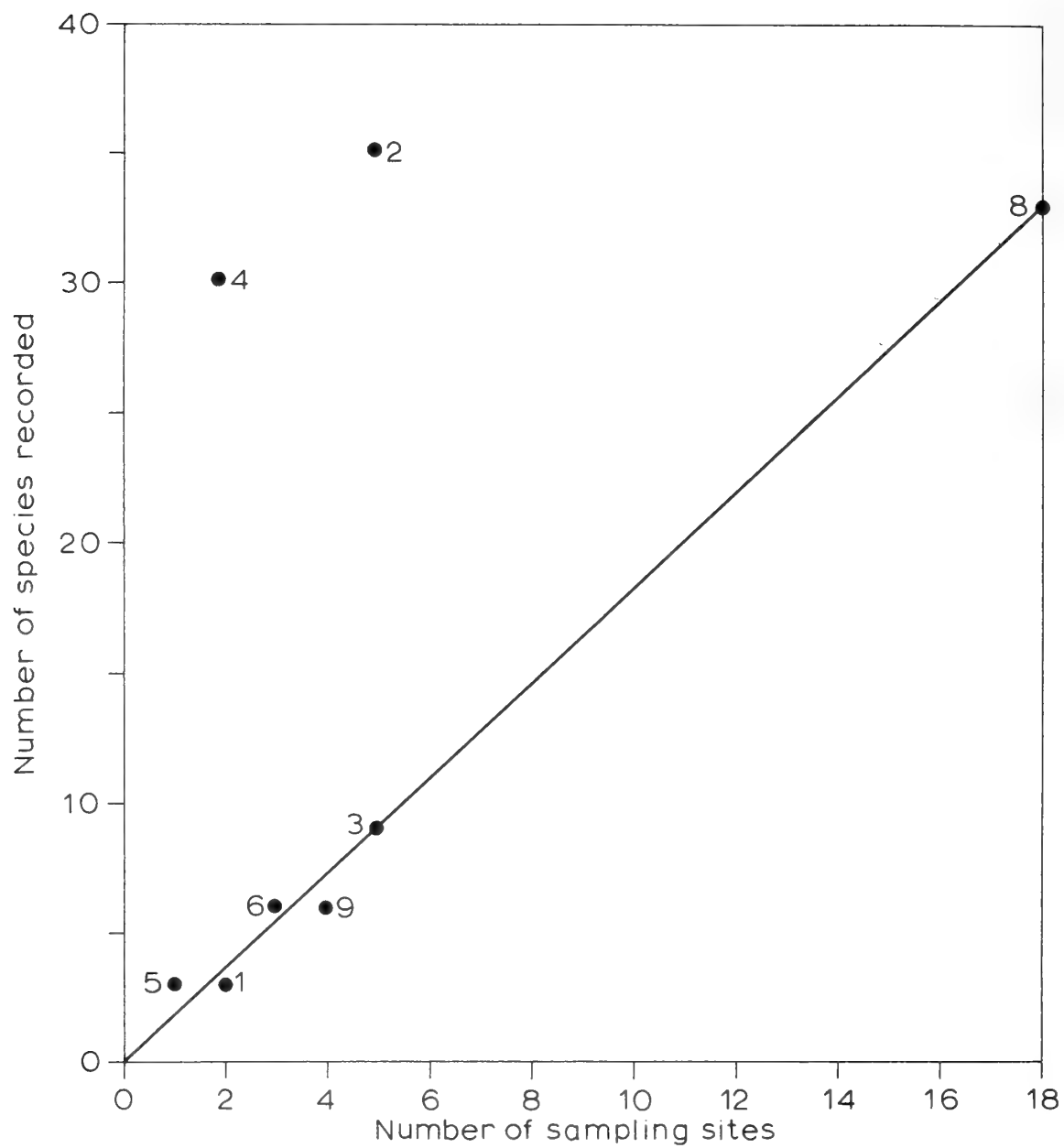


Figure 23. Number of species (other than insects and birds) and sampling sites, Little Cayman, 1975

9. *CERION NANUS* (MAYNARD) (MOLLUSCA: CERIONIDAE) ON LITTLE CAYMAN

M.V. Hounscome and R.R. Askew

Cerion nanus (Maynard) was collected on Little Cayman by Charles Johnson Maynard in the winter of 1888 and described the following year (Maynard 1889). Finding shells in only a very small area (6 yards by 20 yards) he considered 'that this species has the most restricted range of any animal with which I am acquainted'. In 1930 Paul Bartsch visited Maynard's locality and 'gathered two 8 oz. bottles full' of shells (Bartsch 1931). This summarises the reported history of *C. nanus*, a more detailed account being provided by Clench (1964).

Species of *Cerion* are of zoogeographical interest because of their generally restricted distributions. *C. martinianum* (Küster) is known only from Grand Cayman and *C. pannosum* (Maynard) only from Cayman Brac and Little Cayman. These two species differ from *C. nanus* in being closely allied to Cuban species; '*C. nanus* does not appear to be closely related to the other species of *Cerion* on the Cayman Islands or to any *Cerion* from the south coast of Cuba' (Clench 1964). Little Cayman is the only island of the group to support more than one *Cerion* species.

Cerion nanus localities

C. nanus was located at three sites close to each other during the 1975 expedition (Plates 52 and 53). Two sites are adjacent to the North Shore track running from the western end of Blossom Village in a northerly and then north-westerly direction to Spot Bay, and the third site lies along a track running west towards West End Point from the north side of the air-strip.

C. nanus was first found on 25th July at the place, here designated site A (centre at NM 960744), from which the type material described by Maynard was collected. No living *C. nanus* was found although empty shells were spread over a roughly circular area, bisected by the track, of about 35,000 sq.m. This is a much larger area than the 120 sq.m. reported by Maynard. On 2nd August, living snails were found at site B (centre NM 958746) about 350 m. NNW of the

centre of site A. Snails occurred up to about ten metres on either side of the track for a distance of about thirty metres. The third *C. nanus* site, at which again only empty shells were found, extended up to two metres from the track (centre NM 940743) for a distance of about 490 m. Specimens are deposited in the British Museum (Natural History) (accession number 2265) and in the Manchester Museum (accession number 1024). The specimens figured in Plate 54 are in the Manchester Museum (reg. no. EE6001).

Topographically the three sites are similar and of rather distinctive formation. The coral limestone is flat, relatively smooth, and composed of large slabs with accumulations of sandy soil in depressions and cracks. The plant cover is sparse and areas several square metres in extent are devoid of shrubs exceeding about one metre in height. In this open, sun-baked, dry terrain the most conspicuous plant is *Evolvulus arbuscula* Poir. (Convolvulaceae), the crab bush, undoubtedly the 'heath-like plant' referred to by Maynard on which he found *C. nanus*. Living *C. nanus* at site B were found only on *Evolvulus* and the largest accumulations of empty shells at site A were usually beneath *Evolvulus*.

Only one other area that bore a resemblance, at least superficially, to the three *C. nanus* sites was found on Little Cayman. This is a small plateau on the north slope of Sparrowhawk Hill (PM 002781), but no trace of the snail was found here.

E. arbuscula is apparently confined to Little Cayman in the Cayman Islands, but it grows also on Cuba, Hispaniola, Jamaica and the Bahamas. *C. nanus* is very strongly, perhaps exclusively, associated with this plant, although it probably feeds upon epiphytic algae rather than on *Evolvulus* itself. *C. pannosum* is also frequently found on *Evolvulus* but it is plentiful on other plants as well. *C. pannosum* is widespread on Little Cayman, unlike *C. nanus*, and was found at most places visited and in particular abundance on the coastal strip.

Numbers of *Cerion nanus* and *C. pannosum* at sites A and B

Empty shells of *C. nanus* and *C. pannosum* were collected at sites A and B from 0.25 sq.m. quadrats. Twelve quadrats were sampled at site A and eight at site B. At each site, half of the quadrats encompassed *Evolvulus* plants and the remaining quadrats were placed between plants. All empty shells lying within the quadrats were collected and any soil present was sifted for buried shells. Numbers of fully grown and partly grown shells were counted (table 9).

At site A, numbers of living adult and immature *C. pannosum* on 116 *Evolvulus* plants were counted. At site B, numbers of living snails of both *Cerion* species on all the *Evolvulus* present, totalling 157 plants, were counted. These numbers are shown in table 9.

The data in table 9 can be interpreted in a number of ways. If it is assumed that empty shells of the two species persist for about the same length of time and that neither species is preferentially removed from the site, the comparatively low numbers of empty *C. nanus* shells at site A suggest that it has been extinct there for some time and/or it was always less numerous than *C. pannosum*. At site B, empty *C. nanus* shells occur at an insignificantly lower density than at site A, but they comprise a higher proportion of the total number of *Cerion* shells. At site B, fully grown shells of *C. nanus* and *C. pannosum* are present in equal numbers, but at site A fully developed *C. pannosum* shells clearly outnumber those of *C. nanus*. This might indicate a relatively recent colonisation of site B by *C. pannosum*.

Numbers of living snails at the two sites follow the pattern of the densities of empty shells, except for the absence of living *C. nanus* from site A. At site A, numbers of *C. pannosum* per *Evolvulus* plant are very much higher than at site B (8.8 compared with 2.0), consistent with the view that site B is a newly colonised, 'under-saturated' site for this species. Further, the proportion of juvenile to adult *C. pannosum* is much higher at site B (2.6 : 1) than at site A (0.9 : 1).

A feature of the data in table 9 is the relative scarcity of juvenile *C. nanus* in the samples. We are unable to favour any of the several possible explanations of this and the situation requires further investigation.

The numbers of *Evolvulus* plants with and without snails of either species at both sites are given in table 10. Significantly more plants at site A were occupied by snails ($X^2 = 21.1$, $P < 0.001$), adding weight to the supposition that site A is more snail 'saturated' than site B.

Considering the distribution of living snails of the two species on a presence or absence basis over all the plants at site B (table 11), more *Evolvulus* are without snails than would be expected on a random distribution of each snail species. There is, therefore, a tendency for the two species to favour the same *Evolvulus* plants ($X^2 = 9.4$, $P < 0.01$, Cole's Coefficient of Association = 0.53).

Discussion

The occurrence of two species of *Cerion* on Little Cayman, a small island, is unusual. The larger *C. pannosum* is clearly the dominant species, being widespread on the island and occupying a variety of habitats. *C. nanus* is exceedingly localised and appears to be dependant upon *Evolvulus*, although it is by no means found wherever this plant grows. The co-existence of the two *Cerion* species at site B, and their tendency to occur on the same *Evolvulus* plants here, might suggest that interspecific competition is somehow reduced or avoided. On the other hand, in the above account of the situation in 1975, we imply that the two species are unable to co-exist for a prolonged period, *C. pannosum* ultimately replacing *C. nanus*. Such a replacement has certainly occurred at site A, *C. nanus* having

Table 8. Numbers of living adult and juvenile *Cerion nanus* and *C. pannosum* found on *Evolvulus* plants, and the numbers of empty shells of the two species per 0.25 sq.m., at sites A and B.

	<i>Cerion nanus</i>		<i>Cerion pannosum</i>	
	adults	juveniles	adults	juveniles
Living snails				
Site A (116 plants)	0	0	547	468
Site B (157 plants)	78	10	88	226
Mean numbers of empty shells per 0.25 sq.m. (\pm s.e.)				
Site A	17.3 \pm 6.2	0.4 \pm 0.2	31.2 \pm 3.5	29.2 \pm 8.1
Site B	11.6 \pm 4.1	0.5 \pm 0.3	11.6 \pm 3.5	22.8 \pm 10.9

Table 9. Numbers of *Evolvulus* plants with and without *Cerion* of either species at sites A and B.

	with <i>Cerion</i>	without <i>Cerion</i>	number of plants
Site A	108	8	116
Site B	111	46	157

Table 10. Numbers of *Evolvulus* plants carrying live *Cerion* of one or both species at site B. The expected figures assume a random distribution of each species.

Numbers of plants with:	observed	expected
no snails	46	37
<i>C. pannosum</i> only	61	70
<i>C. nanus</i> only	9	18
both species	41	32

disappeared as a living animal during the period since Maynard made his original collection. Whether or not *C. pannosum* occurred at site A when Maynard and Bartsch collected there is unfortunately not known. If, as we incline to believe, continued co-existence of the two species is impossible, *C. pannosum* might be expected eventually to completely displace *C. nanus* from Little Cayman. However, it is difficult to reconcile this simplistic view with the continued presence of *C. nanus*. Why has displacement not already occurred? *C. pannosum* has been on Little Cayman for a long time, as shown by the sub-fossil shells found at various places on the island. It is no recent coloniser. Further, there is no evidence that *C. nanus* was at one time more widespread on the island than it is today.

Further speculation is unlikely to be profitable until more information is available, but the situation is interesting and it is to be hoped that any development on Little Cayman avoids disturbance to the small area where *C. nanus* continues precariously to survive.

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Plate 52. The site on the trans-island track north of Blossom Village where living *Cerion nanus* was found. The snails were living on shrubs of *Evolvulus arbuscula* here seen growing on the path



Plate 53. *Cerion nanus* and young *C. pannosum* on a single plant of *Evolvulus arbuscula*. Inset: a living specimen of *C. nanus*

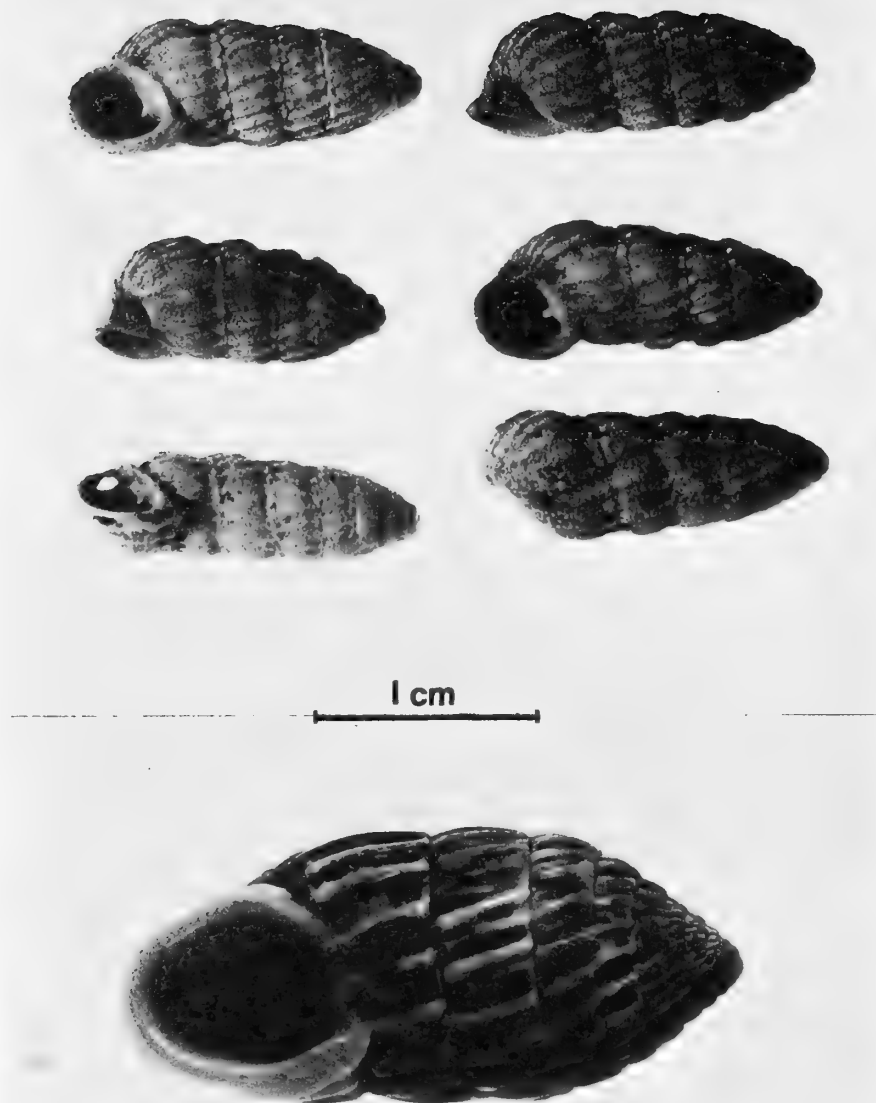


Plate 54. Six shells of *C. nanus* with an example of *C. pannosum* for comparison (to the same scale). Four typical shells are shown together with two examples of extremes in length/height ratio

10. THE INSECT FAUNA OF LITTLE CAYMAN

R.R. Askew

Little Cayman is seldom mentioned in entomological literature. The 1938 Oxford University Biological Expedition spent thirteen days on the island and reports on the resulting collection deal with Odonata (Fraser, 1943), water-bugs (Hungerford, 1940), Neuroptera (Banks, 1941), cicadas (Davis, 1939), Carabidae (Darlington, 1947), Cerambycidae (Fisher, 1941, 1948), butterflies (Carpenter & Lewis, 1943) and Sphingidae (Jordan, 1940). During the 1975 expedition, insects of all orders were studied over a period of about five weeks and many additions will eventually be made to the island's species list. At present, however, identification of the insects collected has, with the exception of the butterflies which have been considered separately, proceeded in the majority of cases only as far as the family level. Application of family names for the most part follows Borror & DeLong (1966). In this paper the general characteristics of the insect fauna are described.

Collecting Methods

- A. General collecting with sweep-net, pond-net, butterfly net and searching foliage, tree trunks and on the ground. A cone-net attached to a vehicle was used on one occasion. Also considered as being caught by 'general collecting' are insects found resting on walls adjacent to outside electric lights at Pirates' Point.
- B. A Malaise trap (Model 300 Health-EE-X supplied by Entomology Research Institute, Minnesota) was erected on 17th July and operated almost continuously to the end of the expedition. It was situated at Pirate's Point, just south of the lagoon and road, in a glade between bushes of *Conocarpus* and other shrubs growing at the base of the northern face of the beach ridge. The ground vegetation was dominated by *Sporobolus* and *Ambrosia*. The trap was unbaited; 70% ethyl alcohol was used in the collecting beaker.

- C. A Robinson mercury vapour light trap, powered by a portable generator, was run in the grounds of Pirate's Point on the following occasions: 14th July (20.00-22.00 hours), 15th July (20.00-22.00), 16th July (20.00-22.00), 17th July (20.00-22.00), 18-19th July (22.00-4.00), 19-20th July (21.00-4.00), 21-22nd July (22.00-4.00), 24th July (20.00-21.30), 27th July (20.00-3.30) and 30th July (20.30-21.30 hours, when the generator irreparably broke down). The trap was also run on 28th July in the central forest south of Sparrowhawk Hill from 18.30 to 21.30 hours. Few insects arrived after 21.00 hours.
- D. Other collecting methods attempted, with very poor results, were the use of a yellow trap, pit-fall traps and extraction funnel (charged with washed-up turtle grass).

The Fauna in General

By the methods outlined above, at least 613 insect species were collected. Closer examination of the material will probably reveal further species. Representatives of all orders except Protura, Plecoptera, Embioptera, Zoraptera, Anoplura, Strepsiptera, Mecoptera, Trichoptera and Siphonaptera were found. Only a few vertebrates were examined for ectoparasites and Siphonaptera will undoubtedly be present on the island. The other orders listed, if present, should have been detected and it can be concluded that they are represented on Little Cayman at the most by a few, rare species.

The numbers of species found in each order are shown in table 12. The ratio of the number of species ($\times 100$) in each order to the number of species recorded in the United States north of Mexico (Borror & DeLong, 1966) is given for comparison. Of the larger orders, the Lepidoptera appear to be best represented although the use of a light trap undoubtedly biased collecting in their favour. The total of species recorded is a minimum; many microlepidoptera caught in the light and Malaise traps could not be identified because of their poor condition. Coleoptera, although the second most numerous order in terms of species caught, is disproportionately poorly represented. Among the smaller orders, Odonata, Orthoptera and Neuroptera are all well-represented. The curve showing the numbers of species recorded over the course of the expedition (fig. 4) only moderately levels off, from which it must be concluded that many more species remain to be discovered.

In terms of individuals, the subjective impression is that Culicidae, Corixidae and Formicidae are the most abundant groups on the island; *Aedes taeniorhynchus* Wied and a species of Corixid were easily the two most frequently encountered species.

Families with the highest numbers of included species are Noctuidae (45 species) and Pyralidae (15), Formicidae (19), Cicadellidae (17) and Staphylinidae (15). Within some of the larger families there is often a wide range of species' size.

Table 12. Ordinal distribution of species of insects found on Little Cayman. Numbers of species from North America north of Mexico are from Borror & DeLong (1966).

<u>Order</u>	Number of species found in		
	<u>Little Cayman</u>	<u>N. America</u>	<u>Ratio x100</u>
Collembola	2	314	0.6
Thysanura	2	50	4.0
Ephemeroptera	1	550	0.2
Odonata	7	412	1.7
Orthoptera	18	1015	1.8
Isoptera	3	41	7.3
Dermaptera	2	18	11.1
Psocoptera	4	143	2.8
Mallophaga	1	318	0.3
Thysanoptera	2	606	0.3
Hemiptera Heteroptera	44	4500	1.0
Hemiptera Homoptera	37	5700	0.6
Neuroptera	9	338	2.7
Coleoptera	118	26576	0.4
Lepidoptera	173	10300	1.7
Diptera	105	16130	0.7
Hymenoptera	85	15218	0.6
Total	613	84061 (including orders not on L.C.)	0.7

Linear measurements of the largest and smallest species within a family are shown in table 13. Individuals of near average dimensions were selected for measurement. Comparable figures for the British fauna are also included in the table and, remembering that these are drawn from a generally much larger fauna, they emphasize the often considerable within-family size range of Cayman insects. This is particularly true for Lepidoptera, Orthoptera, and for some families of Coleoptera but not Carabidae or Staphylinidae. Large Carabids and Staphylinids seem to be absent and this may be because of exclusion by the many land crabs on Little Cayman. The range of size appears to be greatest in endopterygote families (except Diptera). In terrestrial exopterygote species, adults and immature stages often have a similar biology and this may suppress the establishment of species that are small as adults.

The large size range within families of Cayman insects is contributed to by both very small and very large species, but especially by the latter. In orders in which more than two representatives were found, the Diptera and Hymenoptera are the only ones in which a British species exceeds in linear dimensions the largest Cayman species obtained.

COLLEMBOLA

Neanuridae 1 species Entomobryidae 1 species

The Neanurid, a pinkish-orange species, occurred in aggregations on the surface of rain-water in pit-fall traps. The Entomobryid was found amongst litter near Spot Bay and, apparently the same species, in accumulations of washed-up turtle grass on the shore.

THYSANURA

Lepismatidae 2 species

EPHEMEROPTERA

Baetidae 1 species

A subimaginal skin and a live larva found in a rain-water pool on the bluff south of Crawl Bay.

ODONATA

Aeshnidae 1 species Libellulidae 6 species

Dragonflies were conspicuous and abundant, especially near to the brackish coastal lagoons and on the *Sesuvium* marsh in the east. No Zygoptera were noted on Little Cayman, although two species were found on Grand Cayman together with three species of Anisoptera not encountered on the smaller island. Fraser (1943) records twelve species of Odonata collected by the Oxford University expedition (six

Table 13. Within-family size ranges of Little Cayman and British insects.

Dimensions are body length (excluding antennae and abdominal appendages) except for Odonata, Neuroptera and Lepidoptera where wing expanse is given, and Scarabaeidae for which elytral length is shown.

<u>Order</u>	<u>Family</u>	Dimensions (mm.)	Magnitude range	
		of largest species (Little Cayman)	L. Cayman	Britain
Odonata	Libellulidae	82	1.5	1.6
Orthoptera	Blattidae	39	4.6	1.7
	Gryllidae	15	3.3	2.5
Heteroptera	Miridae	4.5	2.3	3.9
Homoptera	Cicadellidae	4	2.4	4.7
Neuroptera	Myrmeleontidae	118	2.1	-
Coleoptera	Carabidae	10	5.0	12.4
	Staphylinidae	12	6.7	11.7
	Hydrophilidae	38	20.0	20.0
	Elateridae	28	4.7	2.4
	Cerambycidae	(52)*	(10.4)	5.2
	Scarabaeidae	25	10.0	9.5
Lepidoptera	Sphingidae	143	4.6	2.7
	Noctuidae	148	6.7	4.6
	Pieridae	60	2.3	1.5
	Hesperiidae	49	2.1	1.3
Diptera	Chloropidae	2	1.8	5.0
Hymenoptera	Formicidae (workers)	7.1	5.1	4.7
	Sphecidae	23	5.1	7.0
	Braconidae	9	6.0	9.8

* species found on Cayman Brac

from Little Cayman) although not all are the same as those taken in 1975. The most numerous species, *Erythrodiplax naeva* (Hagen), was found all over the island including the dry interior. A larger *Pantala* species was also common but confined to the vicinity of coastal lagoons where large 'flocks' were frequently seen hawking until sunset at a height of about five metres.

ORTHOPTERA

Acrididae 1 species (Cyrtacanthacridinae)
Tettigoniidae 4 species (2 Conocephalinae, 2 Phaneropterinae)
Gryllidae 6 species (3 Mogoplistinae, 2 Oecanthinae,
1 Gryllinae)
Phasmidae 1 species Blattidae 6 species

The dominance of the terrestrial crickets and cockroaches over the other families may be related to the abundance of arboreal lizards. The Phasmid and the two Phaneropterinae, all tree-living, were each found only once. The Acridid, a large species, was widespread in all stages. An Oedipodine grasshopper with red hindwings was collected on Cayman Brac but not found on Little Cayman.

ISOPTERA

Kalotermitidae, Termitidae, Rhinotermitidae (1 species each)

Little time was spent in collecting termites and more species are to be expected.

DERMAPTERA

Labiduridae 1 species (*Labidura riparia* (Pallas))
Labiidae 1 species (*Barygerax* sp.)

Only three specimens of earwig were found. The order has not hitherto been reported from the Cayman Islands and the *Barygerax* species is probably undescribed (teste A. Brindle).

PSOCOPTERA

The four species found, represented by only four individuals, are not yet identified to family.

MALLOPHAGA

A single biting louse was taken from a red-footed booby. Few other birds were examined.

THYSANOPTERA

Phloeothripidae 1 species Family ? 1 species

No special effort was made to locate thrips and the order is probably under-represented in the collections.

HEMIPTERA HETEROPTERA

Corixidae 2 species
 Notonectidae 2
 Veliidae 1
 Anthocoridae 4
 Miridae 7
 Isometopidae 1
 Reduviidae 2
 Nabidae 1
 Tingidae 3
 Lygaeidae 4
 Pyrrhocoridae 3
 Coreidae 3
 Corizidae 3
 Saldidae 1
 Scutelleridae 4
 Pentatomidae 4

Corixidae were exceedingly abundant, coming to the mercury vapour trap in enormous numbers and often being seen in the brackish lagoons. One species dominated the collections, but more than two species may eventually be found to be present. Hungerford (1940) records only one water bug, *Trichocorixa verticalis* (Fieb.) from Little Cayman.

Most of the terrestrial species were rather local but sometimes plentiful. One of the Pyrrhocorids aggregated in large numbers on fallen fruits, and another was common on cultivated bean plants.

HEMIPTERA HOMOPTERA

Cicadidae 1 species	Membracidae 1 species
Cicadellidae 17	Tropiduchidae 1
Flatidae 3	Delphacidae 7
Cixiidae 4	Acanaloniidae 1
Aphididae 1	Aleyrodidae 1

Striking features of the Homopteran fauna are the paucity of Sternorhyncha and the apparent absence of Cercopidae.

NEUROPTERA

Mantispidae 1 species	Chrysopidae 3 species
Ascalaphidae 1	Myrmeleontidae 4

Neuroptera are very well-represented, in spite of the absence of Hemerobiidae. This latter may be related to the scarcity of aphids. The ant-lions were all collected as adults at light and two species were common. Banks (1941) reports the presence on

Little Cayman of *Chrysopa transversa* Walker and *Myrmeleon insertus* Hagen only, from material collected by the 1938 Oxford University expedition. Both of these species were found in 1975. No Mantispid has hitherto been reported from the Cayman Islands.

COLEOPTERA

Cicindelidae 2 species	Carabidae 11 species
Dytiscidae 2	Hydrophilidae 9
Leptodiridae 1	Staphylinidae 15
Pselaphidae 1	Orthoperidae 1
Cisidae 1	Cleridae 2
Elateridae 5	Buprestidae 1
Heteroceridae 1	Derodontidae 1
Rhizophagidae 2	Silvanidae 1
Phalacridae 1	Lathridiidae 2
Coccinellidae 6	Colydiidae 1
Anthicidae 1	Euglenidae 1
Oedemeridae 5	Meloidae 1
Mordellidae 1	Alleculidae 2
Tenebrionidae 1	Anobiidae 2
Bostrichidae 2	Scarabaeidae 10
Cerambycidae 9	Chrysomelidae 3
Bruchidae 4	Curculionidae 6
Platypodidae 2	Scolytidae 2

Two families of terrestrial carnivores, Carabidae and Staphylinidae, contain the highest numbers of beetle species found. Becker (1975) shows that the beetle fauna of islands tends to include a higher proportion of terrestrial carnivores than does the fauna of the adjacent mainland, and he postulates that carnivorous beetles, being more catholic in food requirements than most phytophagous species, are more easily able to become established on islands. On Little Cayman the percentage of terrestrial carnivorous species (counting only Cicindelidae, Carabidae, Staphylinidae, Cleridae and Coccinellidae) in the total number of phytophagous species (Buprestidae, Bostrichidae, Cerambycidae, Chrysomelidae, Bruchidae and Curculionidae only) plus terrestrial carnivores is 59. Corresponding figures given by Becker for Jamaica and Cuba are 66% and 41% respectively, whilst percentages for mainland Latin America range only between 21 and 37. All Carabids and Staphylinids found on Little Cayman are fully winged and all species were taken at light at night. The generally small size of the species is discussed above.

Another ecological group of beetles well-represented on Little Cayman comprises species that feed as larvae in wood and Cerambycidae are especially common. Beetle borings were noted in stems of *Avicennia*, *Conocarpus* and *Rhizophora*.

LEPIDOPTERA

Rhopalocera 23 species (details elsewhere)

Sphingidae 11	Noctuidae 45
Pericopidae 1	Syntomidae 4
Cossidae 1	Notodontidae 1
Agaristidae 1	Psychidae 1
Arctiidae 2	Geometridae 13
Pyralidae 15	'Microlepidoptera' 39
Family ? 16	

Family identifications of the moths, particularly Microlepidoptera, are as yet incomplete. There are probably many more species of the smaller moths than are listed here; many were caught in the light trap and have been badly damaged by the enormous numbers of ants and Corixids that were also captured. Proper investigation of the Microlepidoptera requires a specialist able to study them full-time.

A feature of the light trap collections was the abundance of small moths and of the larger Sphingidae. The intermediate size range appeared to be under-represented compared with samples from temperate Europe. Most of the Noctuidae are small, but a single specimen of the very large *Ascalapha odorata* (L.) was found dead in the house at Pirate's Point. Jordan (1940) lists five species of Sphingid from Little Cayman, all of which were taken again in 1975 together with six more species.

A number of species captured at outside electric lights were not represented in the light trap samples. Some of these were among the most colourful species found and included *Noropsis hieroglyphica* Cr. and *Xanthopastis timais* Cr. (Noctuidae).

Two brightly coloured day-flying species, *Composia fidelissima* H.-S. (Pericopidae) and *Utetheisa* species (Arctiidae), were frequently seen, and another Arctiid, *Calidota strigosa* Wlk., was captured both in the light trap and at the house lights.

DIPTERA

Psychodidae 1 species	Culicidae 6 species
Ceratopogonidae 4	Chironomidae 1
Sciaridae 3	Cecidomyiidae 3
Stratiomyidae 3	Tabanidae 2
Asilidae 1	Empididae 1
Therevidae 3	Bombyliidae 6
Dolichopodidae 8	Syrphidae 4
Otitidae 7	Tephritidae 5
Sepsidae 1	Lauxaniidae 4
Lonchaeidae 3	Ephydriidae 3
Drosophilidae 1	Chloropidae 9
Agromyzidae 3	Clusiidae 1
Asteiidae 1	Hippoboscidae 1
Streblidae 1	Calliphoridae 2
Sarcophagidae 5	Tachinidae 9
Muscidae 3	

In terms of numbers of individuals, the Culicidae is probably the most abundant insect family on the island. *Aedes taeniorhynchus* swarmed everywhere except on the beaches and in the central forest. It was especially abundant in mangroves and at the edges of the brackish lagoons, and females would feed at any time of day, sometimes on being disturbed from vegetation. Numbers increased noticeably on 26th July, three days after torrential rain. No special effort was made to collect mosquitoes on Little Cayman. The Mosquito Research and Control Unit has recorded 17 species from Little Cayman and 29 species from neighbouring Cayman Brac (M.E.C. Giglioli, pers. comm.).

Of the higher flies, the only conspicuous species are the Bombyliids. These were to be seen hovering over vegetation or resting on the ground, and they seem to occupy the place filled by Syrphidae in temperate regions. Syrphids are rather scarce although a large species was frequently seen, especially in the interior of the island. A species of *Microdon* was taken in some numbers in the Malaise trap, but not observed elsewhere. A *Tabanus* flew around members of the party still wet after bathing in the sea but no other Diptera were conspicuous in the field and the numbers of species captured in the Malaise trap was somewhat unexpected. Chloropids, Dolichopodids and Tachinids were families represented by most species in the Malaise trap. Some of the species of Sarcophagidae and Tachinidae are grey and black flies with reddish apices to their abdomens, and they superficially resemble two Sphecids wasps with similar colouration.

Two species ectoparasitic on vertebrates were found. The Hippoboscids were collected in the Malaise trap; the Streblid was taken from a specimen of the bat *Macrotus waterhousii* Gray.

HYMENOPTERA

Braconidae 11 species	Ichneumonidae 3 species
Eulophidae 10	Elasmidae 3
Encyrtidae 1	Eupelmidae 1
Torymidae 5	Pteromalidae 4
Eurytomidae 2	Chalcididae 1
Cynipidae 2	Ceraphronidae 1
Scelionidae 3	Diapriidae 1
Bethylidae 1	Tiphiidae 1
Mutillidae 1	Rhopalosomatidae 1
Formicidae 19	Vespidae 1
Pompilidae 1	Sphecidae 8
Megachilidae 1	Colletidae 1
Halictidae 2	

Formicidae dominate the hymenopterous fauna on Little Cayman and are probably exceeded in numbers of individuals only by Culicidae and Corixidae. All of the wasp species found (Sphecidae, Pompilidae, Vespidae, Rhopalosomatidae, Mutillidae, Tiphiidae) were frequent to abundant, but the bees (Colletidae, Halictidae, Megachilidae) were scarce.

Two Bembicine (Sphecidae) wasps were especially numerous, the large *Stictia signata* (L.) and a smaller species. The former is widespread on the island and nests in colonies in sandy ground where dappled shade is provided by trees and shrubs. The smaller Bembicine species is found around the coast but not in the interior, again nesting in sandy ground but usually where there is no shade.

Of interest is the fact that five of the thirteen wasp species provision their nests with crickets which are well-represented on Little Cayman. These are the Rhopalosomatid, a generally rare group but one species of which was taken in some numbers at night in the Malaise trap and light trap, and four Sphecid species (two Larrini, two Chlorionini - *Sphex* sp. and *Prionyx* sp.). Of the remaining wasps, three prey upon Endopterygote larvae (the Vespidae (Eumeninae), Mutillid and Tiphiid), three upon flies (the two Bembicini and one Oxybelini), and two upon spiders (the Pompilid and *Sceliphron jamaicense* (F.)).

The majority of species of parasitic Hymenoptera was obtained whilst sweep-netting on the disturbed ground of the old coastal plantations. In general they are rather scarce, an opinion reinforced by the small numbers caught in the Malaise trap. Only Braconidae and Eulophidae were represented by fairly large numbers of species, and their relatively high frequency is probably related to the many species of Microlepidoptera found on the island. Ichneumonidae are distinctly scarce and it is suggested that their niche on Little Cayman is occupied by the rather large number of Tachinid (Diptera) species.

No species of Symphyta was found.

Sweep-net samples

Eleven samples were collected with a sweep-net at various localities and on different dates. No attempt was made to standardise the amount of time spent in collecting each sample. Catches were small. In seven of the samples, Hemiptera Heteroptera are the most numerous group, in two Hemiptera Homoptera, and in one each Coleoptera and Hymenoptera Parasitica.

Janzen and Pond (1975) present data from standardised sweep-net samples of secondary vegetation in England and Michigan (U.S.A.). Their catches from Michigan are shown in table 14 together with the total Little Cayman catch. Although detailed comparisons between the two samples can not be made because of differences in collecting methods, it is likely that the more marked disparities reflect real differences between the two areas. Percentage representation of exopterygotes is greater in the Cayman samples; of endopterygote groups only Hymenoptera Aculeata and Coleoptera on Little Cayman slightly exceed their representation in the Michigan samples. Species of Diptera are markedly less well-represented in the Cayman samples. Janzen and Pond compare their temperate latitude samples with those collected in a comparable manner in Costa Rica, and draw attention to

Table 14. Percentage composition of sweep-net samples from Little Cayman compared with those reported by Janzen and Pond (1975) from Michigan, U.S.A.

	Little Cayman		Michigan	
	<u>species</u>	<u>individuals</u>	<u>species</u>	<u>individuals</u>
Orthoptera	5.4	5.3	1.6	0.8
Psocoptera	1.5	0.4	0	0
Hem. Heteroptera	14.6	36.0	7.5	12.1
Hem. Homoptera	16.9	10.6	13.2*	27.8
Thysanoptera	0.8	0.2	?	'many'
Neuroptera	0.8	0.6	0	0
Coleoptera	10.0	12.8	9.1	5.0
Mecoptera	0	0	0.3	0.1
Lepidoptera	3.1	1.0	4.7	0.8
Diptera	17.7	12.7	32.7	16.1
Hym. Aculeata	9.2	9.6	8.2	31.7
Hym. Parasitica	20.0	10.8	22.6	5.5
N	130	491	318	3963

* Excluding aphids

the preponderance of Orthoptera and other large exopterygotes in the tropical sample. They suggest as a reason the lack of seasonal constraints upon growth in the tropics. The smaller exopterygotes (Homoptera and Thysanoptera) are probably better represented in temperate regions, although aphids have been claimed (Janzen, 1973) to be a prominent feature of the insect fauna of Caribbean islands. This is certainly not the case on Little Cayman where the paucity of aphids resembles the situation in Costa Rica (Janzen & Pond, 1975).

Ants are relatively very abundant in the tropics; eleven of the twelve species of aculeate Hymenoptera in the sweep-net samples from Little Cayman are ants and they comprise all but one of the aculeate individuals swept. In Michigan only eleven of the twenty-six aculeate species collected by Janzen and Pond are ants.

The abundance of parasitic Hymenoptera in temperate latitudes, compared with their status in the tropics, is often remarked upon. Although it was my impression that Parasitica were scarce on Little

Cayman, they did feature quite prominently in the sweep-net collections. It is possible, however, that there was some sampling bias towards their collection.

The estimated species diversity of the Little Cayman samples is less than that of the Michigan samples. Margalef's index of species diversity is 20.8 for Little Cayman and 38.3 for Michigan, although the Michigan value would probably be lower if aphids and thrips could be included in its calculation. Nevertheless, the low value for Little Cayman is rather surprising and tends to contradict the general rule that the diversity of tropical faunas is greater than that of temperate regions.

Malaise trap samples

The Malaise trap was operated for eight non-consecutive 24-hour periods and for five additional daytime (6.00 - 18.00 hours) periods. Total catches obtained are given in table 15 and, for comparison, data presented by Matthews & Matthews (1971) for Surinam and Kansas. These latter figures can be compared to, and be seen to agree closely with, the 24-hour catches percentage representation of orders by individuals on Little Cayman. The Kansas sample (Marston, 1965) was obtained over a length of time similar to that for the Little Cayman sample, and it is interesting that the total numbers of insects caught at the two places are also fairly close.

Diptera are typically the dominant order in Malaise trap samples, with Hymenoptera generally occupying the second position (Matthews & Matthews, 1971). In the Little Cayman samples Diptera are the most abundant order, but second place is shared by Hemiptera and Hymenoptera, reinforcing the view suggested by the sweep-net samples that certain Hemiptera are particularly well-represented on Little Cayman. The Surinam sample includes few Hemiptera.

From the daytime catch of 900 insects in 60 hours it can be estimated that the 24-hour catches of 2149 insects are composed of approximately twice as many insects caught during daylight than at night. Differences in percentage representation between the 12-hour and 24-hour catches concern especially Diptera, with Nematocera, particularly Culicidae, being more active at night and other flies being caught mostly during daytime. Aculeate Hymenoptera are also relatively most frequent in the daytime catch, but the larger percentages of Lepidoptera, Coleoptera and Orthoptera in the 24-hour catches indicate that they, like the Nematocera, are predominantly nocturnally active.

On 20th July the Malaise trap was emptied at 6.00 a.m. and thence every two hours until 6.00 p.m. The greatest number of Diptera was obtained in the pre-noon period with a depression in numbers during mid-afternoon. This parallels the flying activity of butterflies discussed elsewhere. Conversely, Hymenoptera attain maximum activity in mid-afternoon, usually the hottest time of day.

Table 15. Percentage composition of Malaise trap samples from Little Cayman, and from Surinam and Kansas (Matthews & Matthews, 1971).

	Little Cayman				Surinam Kansas	
	24 hr. periods		12 hr. (day) periods			
	spp.	inds.	spp.	inds.	individuals	
Odonata	0.6	0.1	0	0	<0.1	0.1
Orthoptera	2.9	0.8	1.0	0.1	1.7	0.5
Dermaptera	0.6	0.1	0	0	0	0
Psocoptera	0.6	<0.1	1.0	0.1	0.1	0
Heteroptera	1.8	0.1	2.9	0.4	2.3	6.8
Homoptera	7.6	12.2	6.7	6.0		
Neuroptera	0.6	0.1	0	0	0.4	0.1
Coleoptera	17.6	4.8	9.6	1.3	4.6	5.6
Dipt. Nematocera	5.9	35.9	3.8	3.2	58.0	66.3
Diptera-other	30.6	24.4	48.1	68.6		
Hym. Parasitica	4.7	0.5	3.8	0.6	19.0	12.3
Hym. Aculeata	10.0	11.8	13.5	17.1		
Lepidoptera	16.5	9.0	9.6	2.6	14.0	4.8
(Collembola)	0	0	0	0	0	3.5
N	170	2149	104	900	90182	2927

Margalef's index of species diversity is 22.0 for the 24-hour samples and 15.1 for the daytime samples.

Mercury vapour light trap samples (Macrolepidoptera)

Data on the numbers of species and individuals of Macrolepidoptera caught in the same type of trap as that used on Little Cayman are available for an English site (Woodchester Park, Gloucestershire). On Little Cayman, 457 individuals of Macrolepidoptera belonging to 66 species were caught at Pirate's Point over a period of ten nights (37 hours). The species diversity values are 10.6 (Margalef) and 20 ± 3 (Williams). These are greater than those obtaining in any year at Woodchester Park where traps were operated in periods during June or July (table 16). The English samples resulted from all-night collections, whereas the Little Cayman samples were biased towards moths flying in the early part of the night. This bias would probably depress the species diversity indices for Little Cayman and

Table 16. Comparison of light trap catches of Macrolepidoptera on Little Cayman and at Woodchester Park, Gloucestershire, England.

		Numbers of			Estimates of species diversity	
		spp.	inds.	moths/trap/hr.	Williams	Margalef
Woodchester	1968	73	2783	107	14±5	9.1
"	1969	72	3368	37	14±5	8.7
"	1970	57	3314	61	9.5±5	6.9
"	1971	54	605	13	14±7.5	8.3
Little Cayman	1975	66	457	12	20±3	10.6

the figures may be taken to indicate a truly higher diversity of Macrolepidoptera on Little Cayman. On Little Cayman moths were captured at the low rate of only twelve an hour, and this compares unfavourably with the rate of capture at the English site, although comparisons of these figures are of doubtful value because so many variable factors are involved.

The single night's trapping in the central forest south of Sparrowhawk Hill yielded 90 Macrolepidoptera of 25 species. This is too small a sample to give a reliable diversity estimate, but it is interesting that eight of the species were not caught at Pirate's Point. These are species belonging to families other than Sphingidae and Noctuidae; all Sphingids and Noctuids caught in the central forest were found also at Pirates' Point, perhaps a demonstration of the strong-flying, dispersive flight-activity in these two families.

Comparison of collecting methods

The numbers of species caught by general collecting (as defined on page 97), the Malaise trap and the light trap are shown in table 17. Most species were caught by general collecting, fewest in the Malaise trap. The Malaise trap, however, caught considerably more Diptera than were taken by either of the other two methods, whilst most species of both Coleoptera and Lepidoptera were captured in the light trap. General collecting yielded most species of the other groups. The high numbers of Coleoptera and Hemiptera taken in the light trap are noteworthy and may be related to a high incidence of nocturnal activity in these orders. Hemiptera, at least, are generally considered as predominantly diurnal insects. Malaise trap samples also suggest that many insects on Little Cayman are nocturnal. The obvious explanation is the high density of day-active lizards on the island.

Since the Malaise trap was operated only at Pirates' Point, and the light trap mostly at this site, it is not surprising that seventy-four percent of species found on Little Cayman were taken at Pirate's Point. Forty-nine percent were found elsewhere on the island, twenty-three percent being captured at both Pirate's Point and elsewhere.

Discussion

The size of the insect fauna of Little Cayman is probably in accord with the area of the island. Brackish lagoons occupy a considerable part of the island and insects able to develop in their waters comprise a major element in the entomofauna. Culicidae, Corixidae and Odonata may be cited in this respect. Of terrestrial groups, attention has been drawn already to the abundance of most groups of exopterygote insects. Orthoptera tended to occur in the undisturbed interior of the island, but the majority of Hemiptera were found around the coast and many may well owe their presence on Little Cayman to the affect man has had on the coastal vegetation. Many endopterygote species also were found only on the disturbed ground of the coastal strip; this is true especially for parasitic Hymenoptera. Coleoptera and Diptera were widespread but, although quite rich in species and families, with the exception of mosquitoes seemingly in relatively low numbers. This apparently high diversity is expected in a tropical region although it can be quantitatively shown only for Macrolepidoptera. Species diversity in Malaise trap and sweep-net samples is not high.

Two biotic features of Little Cayman probably have an unusually strong influence on the entomofauna. These are the abundance of land crabs and arboreal lizards, the possible effects of which are discussed above.

On specific identifications so far made, it appears that Little Cayman shares much of its insect fauna with Cuba and Jamaica. The seemingly low incidence of endemism is probably a product of a relatively short sea distance (about 200 km.) separating Little Cayman from Cuba and Jamaica, together with a high incidence of very strong winds in the region. Only a very few flightless species were found.

Three areas on Little Cayman are of special interest in supporting species not found elsewhere and in having an apparently unmodified flora. These areas are the central forest south of Sparrowhawk Hill, the *Sesuvium* marsh at the eastern end of the island, and the interior scrub adjacent to the north shore track about one kilometre north of Blossom Village. It is in these areas that endemic species are most likely to occur.

Table 17. Numbers of species caught by different methods on Little Cayman.

Figures in parentheses show the numbers of species caught only by the method indicated, and the percentages are of the number of species caught by each method out of the total number of species found on the island belonging to the group.

	General collecting		Malaise trap		Light trap	
	species	%	species	%	species	%
Apterygota, Exopterygota (excl. Hemiptera)	36 (30)	85.7	9 (3)	21.4	4 (3)	9.5
Heteroptera	34 (21)	77.3	6 (2)	13.6	17 (8)	38.6
Homoptera	23 (16)	62.2	14 (7)	37.8	10 (5)	27.0
Neuroptera	7 (3)	87.5	1 (0)	12.5	5 (1)	62.5
Coleoptera	49 (25)	41.5	34 (13)	28.8	69 (52)	58.5
Lepidoptera	82 (48)	47.4	21 (9)	12.1	114 (78)	65.9
Diptera	36 (18)	34.3	78 (54)	74.3	20 (6)	19.0
Hymenoptera	57 (39)	67.1	33 (17)	38.8	19 (10)	22.4
Totals	324 (200)	52.9	196 (105)	32.0	258 (163)	42.2

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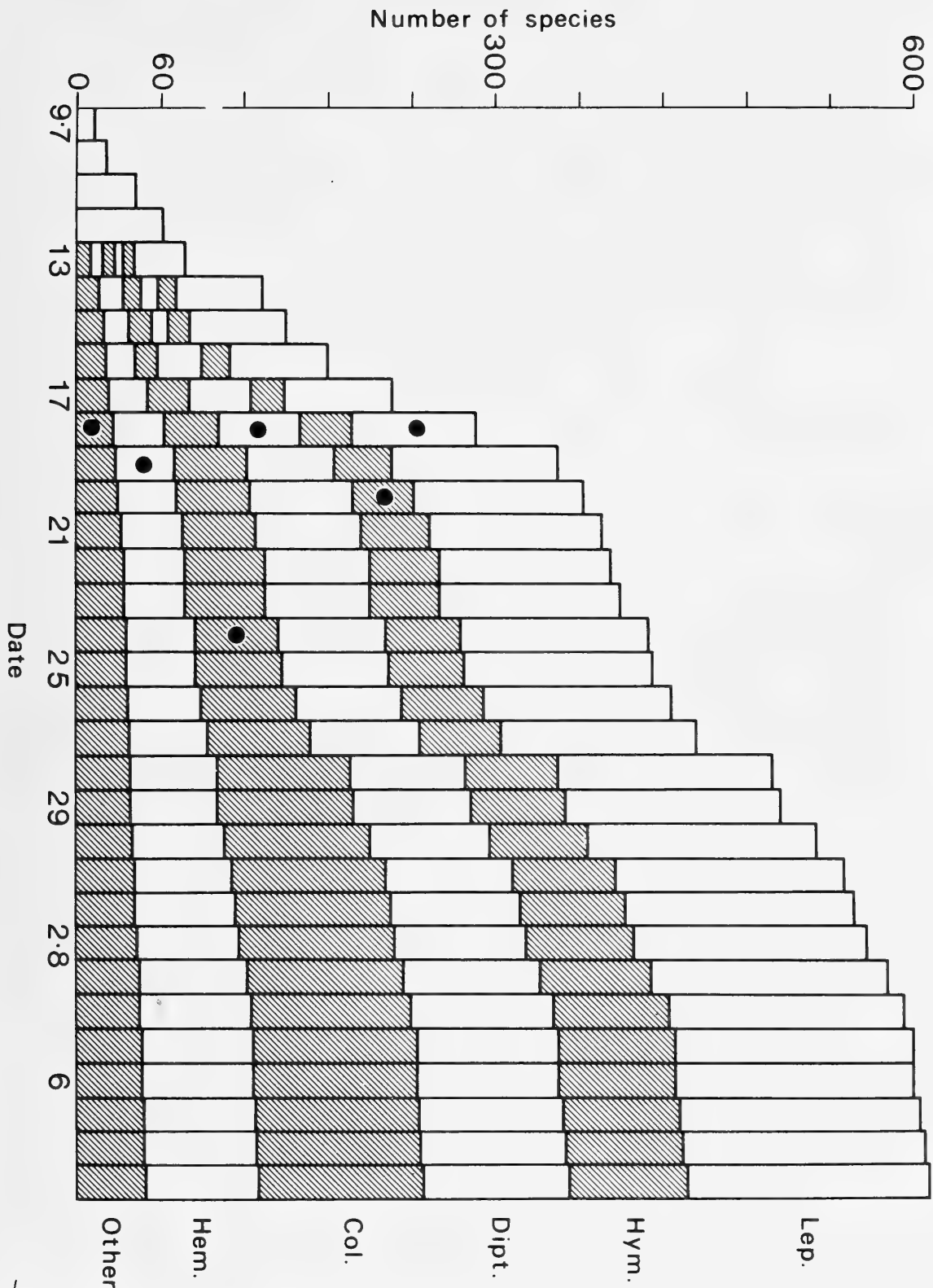


Figure 24. The progression of insect species recorded on Little Cayman by dates. Full circles signify dates on which half the final total of species in each group were found. The light trap was first operated on 14 July, the Malaise trap on 16 July, and the main central forest collections were made on 28 July

11. THE ODONATA OF THE CAYMAN ISLANDS, BRITISH WEST INDIES

R.R. Askew

On each of the Cayman Islands there are several lagoons. These are of varying salinity and are undoubtedly the most important breeding sites of dragonflies. There are also accumulations of standing freshwater but these are generally small and mostly temporary. Fraser (1943) provides a synopsis of the types of dragonfly breeding areas found on the islands.

Dragonflies constitute a conspicuous and abundant component of the entomofauna. Published information on the Odonata of the islands appears to be limited, however, to a paper by Fraser (1943) in which the results of the 1938 Oxford University expedition are described.

In 1975 the Royal Society - Cayman Islands Government expedition was based for about five weeks on Little Cayman and eight and four days were spent respectively on Grand Cayman and Cayman Brac. The Oxford University expedition collected mainly on Grand Cayman over a period of 109 days. Twelve species are recorded from the islands by Fraser (1943) and to this number five species can now be added (table 18).

Grand Cayman evidently supports the largest number of species. More were taken there in the few days collecting in 1975 than were taken during the much longer period on Little Cayman. There is little doubt that more species await discovery on Grand Cayman and Cayman Brac, although the list for Little Cayman is probably very nearly complete.

No endemic forms are known on the Cayman Islands, perhaps not surprisingly in view of their proximity to Cuba, Jamaica and Central America. Many of the species recorded are migratory with large geographical ranges, and all are widespread in the Greater Antilles.

Anax amazili (Burmeister)

Two seen hawking over the *Sesuvium* marsh at the east end of Little Cayman, August 5th. The marsh is quite extensive, its eastern

Table 18. Species of Odonata recorded from the Cayman Islands by the 1938 Oxford University Expedition and the 1975 Royal Society-Cayman Islands Government Expedition.

	<u>Grand Cayman</u>		<u>Cayman Brac</u>		<u>Little Cayman</u>	
	<u>1938</u>	<u>1975</u>	<u>1938</u>	<u>1975</u>	<u>1938</u>	<u>1975</u>
ANISOPTERA						
Aeshnidae						
<i>Anax amazili</i>	x	-	-	-	x	x
<i>Gynacantha nervosa</i>	-	x	-	-	-	-
Libellulidae						
<i>Brachymesia furcata</i>	x	-	x	-	x	x
<i>Erythemis plebeja</i>	x	-	-	-	-	-
<i>Erythrodiplax naeva</i>	x	x	x	x	x	x
<i>E. fervida</i>	-	x	-	-	-	-
<i>E. connata</i>	-	-	-	-	?	-
<i>E. umbrata</i>	x	x	x	x	x	x
<i>Lepthemis vesiculosa</i>	x	x	-	-	-	-
<i>Micrathyria didyma</i>	x	-	-	-	-	-
<i>Orthemis ferruginea</i>	x	-	x	-	-	x
<i>Pantala flavescens</i>	x	x	-	x	x	x
<i>P. hymenea</i>	x	-	-	-	x	-
<i>Tramea abdominalis</i>	-	-	-	-	-	x
<i>T. cophysa</i>	x	-	-	-	-	-
ZYGOPTERA						
Lestidae						
<i>Lestes spumarius</i>	x	-	x	-	-	-
Coenagrionidae						
<i>Anomalagrion hastatum</i>	-	x	-	-	-	-
<i>Ischnura ramburi</i>	-	x	-	-	-	-

edge being about 500 metres from the east coast from which it is separated by bluff limestone and storm beach. *Sesuvium* grows luxuriantly over about $\frac{1}{4}$ sq. km. of wet ground interspersed with a number of small, shallow pools. All species of dragonfly recorded by us from Little Cayman were seen at this place.

Gynacantha nervosa (Rambur)

A single female captured flying in a lighted building in Georgetown, Grand Cayman at 1.00 a.m., August 12th.

Brachymesia furcata (Hagen)

Seen on Little Cayman at several lagoons, particularly in the east, between July 30th and August 5th, and also on the storm beaches and occasionally in the interior. It spends much time perching on twigs and is easily recognised by its reddish abdomen and coloured hind wing bases.

Erythemis plebeja (Burmeister)

Not observed in 1975.

Erythrodiplax naeva (Hagen)

The most abundant species and found on all three islands. On Little Cayman it occurred everywhere, very common near the coastal lagoons and on the storm beaches, but also penetrating the interior and being seen at the summit of Sparrowhawk Hill. Throughout the period of the expedition, blackish mature adults and yellow and black immature specimens were noted.

E. fervida (Erichson)

A single female found on uncultivated ground in Georgetown, Grand Cayman on August 13th.

E. connata (Burmeister)

Insects seen but not captured by the 1938 expedition flying over *Zostera* beds inside the fringing reef at Bloody Bay, Little Cayman, are considered (under the name *Erythemis minuscula* (Rambur)) to be referable to *E. connata* (Fraser 1943). *Erythrodiplax minuscula* auct. from the West Indies is *E. connata connata* (Burmeister) (Borror 1942).

E. umbrata (L.)

Recorded from all three islands in both 1938 and 1975. In 1975 it was widespread but not common on Little Cayman, and appeared to be more numerous on the other two islands. On Grand Cayman it was abundant at West Bay. Two mature females and one male only were

taken, a female from Grand Cayman having almost hyaline wings whilst a female from Cayman Brac has very dark wing patches.

Lepthemis vesiculosa (F.)

An attractive green dragonfly with a long, slender abdomen, possibly confined to Grand Cayman. In 1975 it was seen at West Bay on July 6th and a male was taken on August 13th over marshy ground beside the mid-island road.

Micrathyria didyma (Selys)

Not observed in 1975.

Orthemis ferruginea (F.)

A large, red-bodied dragonfly observed quite commonly at the *Sesuvium* marsh, Rosetta Flats and Diggary Point on Little Cayman. The species settles frequently on twigs.

Pantala flavescens (F.)

This large, yellowish dragonfly was common on Little Cayman throughout the period of the expedition, but it was almost confined to areas adjacent to the coastal lagoons. Here numbers could be seen together hawking, probably for mosquitoes, at a height of four or five metres. These flocks dispersed at sunset when the insects went to roost in mangroves fringing the lagoons.

P. hymenea (Say)

Although taken more frequently than the preceding species by the 1938 expedition and found then on Little Cayman, this species was not observed in 1975.

Tramea abdominalis (Rambur)

A single male only of this large red dragonfly with boldly marked hindwing bases was captured, although several were seen, including pairs in tandem, on Little Cayman at Rosetta Flats and the *Sesuvium* marsh. The species settles only rarely and hawks at a height of about five metres.

T. cophysa (Selys)

No examples of this species was noted in 1975. It is said (Needham and Westfall 1955) to be distinguishable in flight from its congener above by its reddish venation and black subterminal abdominal segments.

Lestes spumarius (Selys)

Not observed in 1975.

Anomalagrion hastatum (Say)

A strong colony of this very small damselfly was found on marshy ground beside the mid-island road, Grand Cayman on August 13th.

Ischnura ramuri (Selys)

Several specimens of this damselfly were seen, and a female was taken on uncultivated land in Georgetown, Grand Cayman, on August 13th. The species was not found by the 1938 expedition although Fraser (1943) anticipates its discovery on the islands.

The material collected in 1975 is deposited in the Manchester Museum and British Museum (Natural History).

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12. THE BUTTERFLY (LEPIDOPTERA, RHOPALOCERA) FAUNA OF THE CAYMAN ISLANDS

R.R. Askew

Butterflies are a numerous and conspicuous element in the Cayman Islands insect fauna. Particular attention was paid to them because, with practice, they can be fairly easily identified on sight in the field, and quantitative estimates of their distribution, in the time available, were possible. In addition, the useful baseline study by the 1938 Oxford University Expedition (Carpenter and Lewis 1943) provides data for comparison with the present situation. Butterflies were studied on Grand Cayman and Cayman Brac, during limited periods spent on these islands, as well as on Little Cayman.

Species found on the Cayman Islands by the two expeditions are listed in table 19. Forty species are certainly known from the islands, and this total is probably very nearly complete. A relationship exists between the area of an island and the size of its fauna. A regression of the numbers of species recorded from Cuba, Hispaniola, Puerto Rico, Jamaica and the Cayman Islands on the logarithms of the areas of these islands (fig. 25) suggests that a fauna of forty species from the Cayman Islands is of the right order. Data for the Greater Antillean faunas are taken with modification from Brown and Heineman (1972) and Riley (1975). The number of species on Puerto Rico is perhaps underestimated; Riley gives only eighty certainly recorded species but Brown and Heineman attribute ninety-nine species to the island.

Disparities between the 1938 and 1975 data (table 19) are accounted for by differences in the periods of time spent by the two expeditions on each of the three Cayman Islands, and by the superior mobility of the 1975 expedition due to the provision of vehicles and, on Little Cayman, the cutting of traces by the Cadastral Survey.

Differences between the faunas of Grand Cayman, Cayman Brac
and Little Cayman

Grand Cayman is situated some 117 km. west-south-west of Little Cayman which lies only 7.5 km. east of Cayman Brac. In spite of this proximity, there are differences between the faunas of the three islands.

Grand Cayman is much the largest island and supports the largest number of species (table 19). *Battus polydamas*, *Eurema elathea*, *E. messalina*, *Aphrissa neleis*, *Danaus eresimus*, *Phyciodes phaon*, *Siproeta stelenes*, *Dryas iulia*, *Brephidium exilis* and *Panoquina sylvicola* are all recorded in the Cayman Islands only from Grand Cayman. The place of *Eurema elathea* on the Lesser Caymans may be taken by the closely allied *E. दौरa*. Cayman Brac has no unique species so far recorded in its fauna, but on Little Cayman there are four species, *Papilio aristodemus*, *Nathalis iole*, *Strymon martialis* and *Phocides pigmalion*, which are not yet known from the other two islands.

The unique quality of each island's fauna is further emphasised by the occurrence on Grand Cayman of *Papilio andraemon tailor*i Rothschild and Jordan, a subspecies confined to Grand Cayman and apparently representing the entire population there. *P. a. andraemon* is found on the Lesser Caymans. *Strymon acis* also exists as two fairly distinct forms, one on Grand Cayman and the other on the Lesser Caymans. All specimens of *Junonia evarete* observed on the Lesser Caymans were of the form *zonalis* (Felder and Felder), whereas those captured on Grand Cayman were referable to form *genoveva* (Cramer). This contrasts with the findings of Carpenter and Lewis (1943) who record *genoveva* from both Grand Cayman and Little Cayman, and *zonalis* from Grand Cayman and Cayman Brac. The expression of these two forms is believed to be environmentally controlled, *zonalis* being a wet season form and *genoveva* characteristic of drier conditions; as such their distribution would be expected to vary seasonally and annually.

In addition to qualitative differences between the island faunas, some species vary in relative abundance from island to island. Striking in this respect is *Anartia jatrophae*, abundant on Grand Cayman, scarce on Cayman Brac and absent from Little Cayman. Conversely, *Anaea echemus*, *Appias drusilla* and *Euptoieta hegesia* are very common on Little Cayman but appear to be rare on Grand Cayman.

Notes on the Caymanian species

Unless mentioned to the contrary, the following notes refer to Little Cayman and localities are indicated on the map (fig. 26). Nomenclature follows Riley (1975). Most of the observations on Grand Cayman were made in and adjacent to a small, rather dense, wood behind the Mosquito Research and Control Unit on the edge of Georgetown. This locality is designated 'M'. Collecting on Cayman Brac was

Table 19. Butterfly species recorded by the 1938 and 1975 expeditions to the Cayman Islands.

	<u>Grand Cayman</u>		<u>Cayman Brac</u>		<u>Little Cayman</u>	
	<u>1938</u>	<u>1975</u>	<u>1938</u>	<u>1975</u>	<u>1938</u>	<u>1975</u>
DANAIDAE						
<i>Danaus plexippus</i>	x	x	x	-	-	-
<i>Danaus gilippus</i>	x	x	x	-	x	x
<i>Danaus eresimus</i>	x	x	-	-	-	-
APATURIDAE						
<i>Anaea echemus</i>	x	x	x	x	x	x
NYMPHALIDAE						
<i>Junonia evarete</i>	x	x	x	x	x	x
<i>Anartia jatrophae</i>	x	x	x	x	-	-
<i>Siproeta stelenes</i>	x	x	-	-	-	-
<i>Phyciodes phaon</i>	x	x	-	-	-	-
<i>Euptoieta hegesia</i>	x	x	x	x	x	x
HELICONIIDAE						
<i>Dione vanillae</i>	x	x	x	x	x	x
<i>Dryas iulia</i>	x	x	-	-	-	-
<i>Heliconius charitonius</i>	x	x	-	x	-	x
LYCAENIDAE						
<i>Strymon martialis</i>	-	-	-	-	x	x
<i>Strymon acis</i>	x	-	x	x	x	x
<i>Strymon columella</i>	x	x	-	-	-	x
<i>Hemiargus ammon</i>	x	x	-	x	-	x
<i>Hemiargus hanno</i>	x	x	-	-	-	x
<i>Brephidium exilis</i>	x	-	-	-	-	-
<i>Leptotes cassius</i>	x	x	x	x	x	x
PIERIDAE						
<i>Ascia monuste</i>	x	x	x	x	x	x
<i>Appias drusilla</i>	-	x	x	x	x	x
<i>Nathalis iole</i>	-	-	-	-	-	x
<i>Eurema elathea</i>	x	x	-	-	-	-

Table 19. (continued)

	Grand Cayman		Cayman Brac		Little Cayman	
	<u>1938</u>	<u>1975</u>	<u>1938</u>	<u>1975</u>	<u>1938</u>	<u>1975</u>
<i>Eurema दौरa</i>	-	-	-	x	-	x
<i>Eurema messalina</i>	x	-	-	-	-	-
<i>Eurema nicippe</i>	x	x	x	x	-	x
<i>Eurema lisa</i>	x	x	-	x	-	x
<i>Phoebis sennae</i>	x	x	x	x	x	x
<i>Aphrissa neleis</i>	x	-	-	-	-	-
PAPILIONIDAE						
<i>Battus polydamas</i>	x	-	-	-	-	-
<i>Papilio aristodemus</i>	-	-	-	-	x	x
<i>Papilio andraemon</i>	x	x	x	x	x	x
HESPERIIDAE						
<i>Phocides pigmalion</i>	-	-	-	-	x	x
<i>Urbanus proteus</i>	x	x	x	-	-	-
<i>Hylephila phylaeus</i>	x	-	x	-	-	-
<i>Cymaenes tripunctus</i>	x	x	-	x	-	-
<i>Calpodēs ethlius</i>	-	x	-	-	-	-
<i>Panoquina panoquinoides</i>	x	x	x	x	x	x
<i>Panoquina sylvicola</i>	x	x	-	-	-	-
Numbers of species recorded	32	28	17	18	15	23
Days on islands	109	8	11	4	13	32
Total species on each island	34		22		23	

confined to the western half of the island. The periods spent on each island are as follows: Grand Cayman July 5th - 8th, August 11th - 14th; Cayman Brac July 9th, August 7th - 8th, August 11th; Little Cayman July 9th - August 7th, August 9th - 10th.

1. *Danaus plexippus* (Linnaeus)

Twice seen on Grand Cayman (M). Probably of the subspecies *megalippe* Hübner which replaces, with overlap, the migratory *D. p. plexippus* in the West Indies except on Cuba and the Bahamas.

2. *D. gilippus* (Cramer)

Quite frequent on Grand Cayman (Georgetown dykes, M, West Bay, mid-island road, Old Man Bay). Only seen twice on Little Cayman, at Spot Bay on August 2nd, and at Bloody Bay on August 5th. Of the subspecies *berenice* Cramer.

3. *D. eresimus* (Cramer)

Two collected on Grand Cayman on July 8th (Georgetown dykes, M).

4. *Anaea echemus* (Doubleday and Hewitson)

Abundant on Little Cayman (Preston Bay, Bloody Bay, east end, north shore path, Sparrowhawk Hill, central forest), but seen once only on Grand Cayman (Cayman Kai) and on Cayman Brac. Frequently rests on branches with wings folded. Nine out of fifteen specimens examined had the apical part of one or both hind-wings missing, probably the result of attacks by lizards. Both sexes were strongly attracted by seventy percent ethanol. Of the subspecies *danieliana* Witt.

5. *Junonia evarete* (Cramer)

Common on Grand Cayman (mid-island road, Georgetown dykes, West Bay), and two seen on Cayman Brac. Common on the old plantation ground of Bloody Bay and occurring at other sites on the north and west coasts of Little Cayman. Two observed near Diggary's Point are the only south coast records. Attracted particularly to the flowers of *Stachytarpheta jamaicensis*. Distribution of the forms *zonalis* and *genoveva* is described above.

6. *Anartia jatrophae* (Johansson)

Abundant on Grand Cayman (Georgetown dykes, M, West Bay) but only two seen on Cayman Brac (near the Brown Booby colony) and absent from Little Cayman. This accords closely with the situation recorded by Carpenter and Lewis. In flight throughout the day; one attracted to an outdoor electric light in Georgetown at midnight. Specimens from the Cayman Islands are referred to subspecies *guantanamo* Munroe, described after Carpenter and Lewis attributed their Cayman specimens to *jamaicensis* Möschler.

7. *Siproeta stelenes* (Linnaeus)

One only seen, on Grand Cayman (West Bay) on August 14th. A specimen in the collection of Mr J.F. Lesieur was taken in Georgetown about 1971. Of the subspecies *insularis* Holland.

8. *Phyciodes phaon* (Edwards)

Common in open areas of Grand Cayman (Georgetown dykes, M, mid-island road, West Bay).

9. *Euptoieta hegesia* (Cramer)

Common all round the coast of Little Cayman and not infrequent in the interior scrub. One only seen on Grand Cayman (logwood pasture) and one on Cayman Brac. Specimens very variable, especially in the colour of the hind-wing underside. A fully grown larva collected on August 4th from *Evolvulus arbuscula* (probably not the food plant) produced an imago on August 11th; a pupa produced a brood of a *Pteromalus* species.

10. *Dione vanillae* (Linnaeus)

Abundant and widespread on all three islands. A male was observed attempting to copulate with a female held by a crab spider at Bloody Bay where the species was feeding in numbers at the blue flowers of *Stachytarpheta*. Carpenter and Lewis report that Grand Cayman specimens are on average larger than those from the Lesser Caymans, and this is supported by measurements of material collected in 1975. The fore-wing expanse of Little Cayman specimens ranges from 48mm. to 62mm. (mean 57mm.) for males (n = 9), and from 50mm. to 67mm. (mean 59mm.) for females (n = 6). All three males collected on Grand Cayman exceed the largest Little Cayman male in wing expanse, measuring 71mm., 67mm. and 63mm. Two females were collected on Grand Cayman; one (68 mm.) is larger than any Little Cayman female, and the other (60 mm.) is above the Little Cayman average. Cayman specimens are of the north Caribbean subspecies *insularis* Maynard.

11. *Dryas iulia* (Fabricius)

One specimen collected on Grand Cayman (Georgetown dykes). Caymanian specimens belong to subspecies *carteri* Riley.

12. *Heliconius charitonius* (Linnaeus)

Once seen on Grand Cayman (Georgetown dykes) and once on Cayman Brac. Common in the interior of Little Cayman, especially near taller trees and at the edge of mangrove swamps (Preston Bay, Mary's Bay, Bloody Bay, north shore path, Sparrowhawk Hill, east end, Charles Bight). Brown and Heineman (1972) write "It will take a longer series of specimens than is now available for study to properly place the strain that is found on the Caymans. We suspect that it is distinct from both *H. c. simulator* and *H. c. ramsdeni*". My material is certainly

distinct from the British Museum (Nat. Hist.) series of Jamaican *simulator* Röber in having the yellow markings less extensive, but it does not differ, at any rate superficially, from Cuban *ramsdeni* Comstock and Brown. Carpenter and Lewis found the species only on Grand Cayman, and they record the wing expanse ranging between 64mm. and 94mm. The smallest Little Cayman specimen collected has a wing expanse of 59mm., the largest 94mm.

13. *Strymon martialis* (Herrich-Schäffer)

Seven collected on Little Cayman, all males. Frequently seen about *Conocarpus* at Pirate's Point, and also recorded at Blossom Village on the storm beach, north shore path, Owen Island, and in the interior south of Crawl Bay.

14. *S. acis* (Drury)

Flying with *S. martialis* on *Conocarpus* by the lagoon and on the storm beach at Pirates' Point, also seen at Sandy Point, the storm beach at the east end (on *Caesalpinia*), and at Bloody Bay and Mary's Bay. Two taken on Cayman Brac. The orange spot near the base of the shorter tail on the upper-side of the hind-wing is absent or very small in all specimens, as Carpenter and Lewis reported for their material from the Lesser Caymans. On specimens from Grand Cayman, however, Carpenter and Lewis found the spot well-developed. The 1938 material is placed in the British Museum (Nat. Hist.) with subspecies *gossei* Comstock and Huntingdon from Jamaica. The Grand Cayman insects closely resemble *gossei* but Lesser Cayman specimens are more like Cuban *casasi* Comstock and Huntingdon in pattern.

15. *S. columella* (Fabricius)

The least frequently seen of the three *Strymon* and entirely coastal (Preston Bay, Diggary's Point, Bloody Bay, Mary's Bay, east end). Two captured on Grand Cayman (M). Observed feeding at flowers of *Portulaca* and, like its congeners, flying about *Conocarpus erecta*. Of the subspecies *cybira* Hewitson.

16. *Leptotes cassius* (Cramer)

Carpenter and Lewis list both *L. theonus* (Lucas) and *Hemiargus catalina* (Fabricius). These are conspecific subspecies. Examination of material in the British Museum (Nat. Hist.) indicates that *theonus* is the correct subspecific name for Caymanian insects. Common in open places on Grand Cayman (Georgetown dykes, M, West Bay, South Sound) and Little Cayman (Bloody Bay, Mary's Bay, Preston Bay, Pirates' Point, Blossom Village), and noted on Cayman Brac. Most numerous on the landward slopes of the beach ridges, at a greater distance from the sea than *Hemiargus ammon*.

17. *Hemiargus ammon* (Lucas).

Abundant on the coasts of Grand Cayman (West Bay, South Sound) and

Little Cayman (both north and south coasts); also taken on Cayman Brac (west end). Males are very variable in the degree of expression of the orange spot proximal to the outer black marginal spot on the hind-wing upperside. Of the subspecies *erembis* Nabokov.

18. *H. hanno* (Stoll)

Two females collected on Grand Cayman (West Bay) and two males on Little Cayman (Bloody Bay and, feeding at *Ambrosia hispida*, near the lighthouse). These specimens belong to the subspecies *filenus* Poey.

19. *Brephidium exilis* (Boisduval)

Carpenter and Lewis record this species only from a very limited region of Grand Cayman which they describe as English Sound off Great Sound. Neither of these names is in current use, although Great Sound must refer to North Sound, and the locality is probably to the east of Water Point. This area was visited on August 13th but found to be disturbed by development of Cayman Kai. No butterflies were found. The subspecies *thompsoni* Carpenter and Lewis was described from Grand Cayman specimens.

20. *Ascia monuste* (Linnaeus)

Common on Grand Cayman (M, mid-island road) and Cayman Brac. Abundant on Little Cayman in coastal places, but much less frequent inland although particularly numerous at the east end *Sesuvium* marsh. A large increase in numbers was noted on July 31st. The extent of the apical black dentate mark on the fore-wing upperside is very variable, often reduced, and in one male there is no dentation and the mark closely resembles that of female *Appias drusilla*. Belong on the north Caribbean subspecies *evonima* Boisduval.

21. *Appias drusilla* (Cramer)

Two specimens seen on each of Grand Cayman and Cayman Brac; abundant on Little Cayman in both coastal and inland localities. Most resemble subspecies *poeyi* Butler (all females of the dry season form *peregrina* Röber); Brown and Heineman (1972) wrongly place Caymanian insects as subspecies *castalia* Fabricius (= *jacksoni* Kay).

22. *Nathalis iole* Boisduval

A single female captured on the north shore path about one kilometre north of Blossom Village on August 2nd is the first record of the species from the Cayman Islands. This specimen resembles most closely material in the British Museum (Nat. Hist.) from Texas.

23. *Eurema elathea* (Cramer)

Found only on Grand Cayman (M, Cayman Kai, logwood pasture).

24. *E. दौरa* (Godart)

Not previously recorded from the Cayman Islands. Three males and one female taken on Cayman Brac (west end storm beach, Rebecca's Cave, near the Buccaneer Inn) and four females on Little Cayman (Bloody Bay, Blossom Village, Preston Bay, north coast near Sparrowhawk Hill). The females resemble female *E. elathea* but have less extensive black marginal marks on the hind-wing upperside and the coastal margin of the fore-wing is more strongly curved. The specimens are of the wet season form *palmira* Poey.

25. *E. messalina* (Fabricius)

Carpenter and Lewis record *E. messalina* from Grand Cayman, but it was not found in 1975.

26. *E. nicippe* (Cramer)

Seen on Grand Cayman (M, Cayman Kai) and Cayman Brac. Quite frequent on the north and west coasts of Little Cayman from Bloody Bay to Preston Bay. Only once seen on the south coast, at Diggary's Point. The species was not seen on Little Cayman until July 18th when several were observed at places previously visited.

27. *E. lisa* (Boisduval and Leconte)

Most frequent on Grand Cayman (M, mid-island road, West Bay); common locally on Cayman Brac (west end storm beach) and Little Cayman (Bloody Bay, north shore path, Diggary's Point). Like *E. nicippe*, *E. lisa* was first noted on Little Cayman on July 18th. Cayman insects are of the subspecies *euterpe* Ménétriés.

28. *Phoebis sennae* (Linnaeus)

Frequently observed on all three islands but every active and few caught. Especially numerous in Blossom Village and at Rosetta Flats.

29. *Aphrissa neleis* (Boisduval)

One specimen recorded from Grand Cayman by Carpenter and Lewis. Not seen in 1975.

30. *Battus polydamas* (Linnaeus)

Recorded from the Georgetown area of Grand Cayman by Carpenter and Lewis, but not seen in 1975. The Cayman specimens are of subspecies *cubensis* du Frane.

31. *Papilio aristodemus* Esper

Two captured in 1975 (north shore path, ironshore scrub 1 km. north of Pirates' Point), both *P. a. temenes* Godart.

32. *P. andraemon* (Hübner)

The common swallowtail of the islands. On Grand Cayman (M, Old Man Bay) specimens are clearly referable to subspecies *tailori* Rothschild and Jordan which is large and has reduced yellow markings. On the Lesser Caymans only the smaller, more yellow subspecies *andraemon* is present and widespread. Carpenter and Lewis indicate a difference between Caymanian and Cuban *P. a. andraemon* and their material was submitted to Dr Karl Jordan who noted 'a shifting of characters, perhaps the beginnings of sub-specific separation'. Lesser Cayman material from the 1938 expedition in the British Museum (Nat. Hist.) stand as *P. a. tailori* but I consider them more like Cuban *P. a. andraemon* and prefer to treat them as such. Some Cuban specimens have an orange suffusion over the hind-wing marginal lunules as in two specimens collected north of Charles Bight on Little Cayman.

33. *Phocides pigmalion* (Cramer)

Several seen feeding at flowers of *Rhizophora mangle* growing on the shore at East Rocky Point. They fly high about the mangroves and seldom come within reach of a net. Three males and a female were captured (July 25th, August 9th), of the subspecies *batabano* Lucas. Others were occasionally seen about the mangroves of the north coast. Bates (1935) records larvae feeding on *Rhizophora mangle*.

34. *Urbanus proteus* (Linnaeus)

In 1975 seen only on Grand Cayman (M, West Bay). The West Indian subspecies is *domingo* Scudder.

35. *Cybaeus tripunctus* (Herrich-Schäffer)

Grand Cayman (M) and Cayman Brac (Buccaneer Inn). Two specimens on Cayman Brac were found beneath an outside light at 11.30 p.m.

36. *Hylephila phylaeus* (Drury)

Carpenter and Lewis record *H. phylaeus* 'frequently at the top of beaches' on Grand Cayman and Cayman Brac. It was not found in 1975.

37. *Calpodus ethlius* (Stoll)

A specimen in the collection of Mr J.F. Lesieur collected about 1971 in Georgetown, Grand Cayman. Mentioned as a Caymanian species by Riley (1975) but not recorded by Carpenter and Lewis.

38. *Panoquina panoquinoides* (Skinner)

Frequent on the coasts of all three islands: Grand Cayman (Cayman Kai), Cayman Brac (west end), Little Cayman (Preston Bay, Bloody Bay, east end, Sandy Point, Mary's Bay). Carpenter and Lewis indicate that 'any future expedition should try to discover the food plant and early stages'. The early stages have since been described (see Brown

and Heineman, 1972) and the species reared on *Cynodon dactylon* in Jamaica. This grass does not grow on Little Cayman. Here the insect is always found on beach ridges in areas of *Sporobolus virginicus* which is almost certainly the food plant. Of ten captured on Little Cayman, nine are females. Riley (1975) does not include Cuba in the distribution of *P. panoquinoides* although Bates (1935) records specimens from that island.

39. *P. sylvicola* (Herrich-Schäffer)

Recorded with certainty in 1975 only on Grand Cayman (M), but a dark skipper seen at the east end of Little Cayman may have been this species or the next. Carpenter and Lewis attribute twenty-three of their specimens to form *woodruffi* Watson and two to subspecies *sylvicola*. The specimen that I took is of the former type.

40. *Nyctelius nyctelius* (Latreille)

Not certainly seen in 1975, nor recorded by Carpenter and Lewis, but said by Riley (1975) to occur in the Cayman Islands.

To this list of forty Caymanian species might be added two others whose occurrence on the islands requires confirmation. Carpenter and Lewis (1943) record an unidentified species of *Kricogonia* as seen on Cayman Brac, and these same authors write that *Phoebis agarithe* (Boisduval) has been 'authoritatively reported from Grand Cayman'.

Relationships of the Caymanian fauna

The Cayman Islands are projecting peaks of the submarine Cayman Ridge running westwards from the Sierra Maestra of south-eastern Cuba. Cayman Brac, the island nearest to Cuba and Jamaica, is separated from both by just over 200 km. Between the Cayman Ridge and Jamaica is a 6000 m. deep trench, the Bartlett Deep. The prevailing wind on the Cayman Islands is northerly, blowing from the direction of Cuba.

The butterflies of the Cayman Islands reflect this geographical relationship with Cuba. Brown and Heineman (1972) and Riley (1975) list the recorded butterfly species of Cuba, Hispaniola, Puerto Rico and Jamaica, and their data have been used to calculate values for Cole's coefficient of association between all of these islands and the Cayman Islands. These values, together with the numbers of shared species, are given in table 20. Vagrant or doubtfully recorded species are excluded. Cole's coefficient of association is an index of disequilibrium based upon the difference between the product of the numbers of species found on each of only one of two islands and the product of the numbers of species common to, and absent from, both islands. The coefficient is adjusted to give values between -100 and +100.

Table 20. Matrix showing the numbers of species shared between Cuba, Hispaniola, Puerto Rico, Jamaica and the Cayman Islands (upper right), values for Cole's coefficient of association (lower left), and the total number of butterfly species recorded for each island.

Number of species		Cuba	Hispaniola	Puerto Rico	Jamaica	Cayman Islands
156	Cuba	-	95	68	82	40
152	Hispaniola	-3	-	79	77	32
90	Puerto Rico	34	68	-	63	29
115	Jamaica	22	14	44	-	34
40	Cayman Is.	100	48	57	72	-

A dendrogram (fig. 27) constructed from mean values of Cole's coefficients of association illustrates the close relationship between the faunas of Cuba and the Cayman Islands, with a rather more distant association between the Jamaican and Caymanian faunas. The findings of Clench (1964) and Scott (1972) are essentially similar. All Cayman species are known from Cuba, but fifteen percent of Cayman species are not found on Jamaica. It must be emphasised, however, that the majority of Cayman Island species are widespread in the Greater Antilles, twenty-seven of the forty species being reported from Cuba, Hispaniola, Puerto Rico and Jamaica as well as the Cayman Islands. Associations between island faunas indicated by Cole's coefficient rely heavily upon a relatively small number of more localised species. Only three Caymanian species (*Anaea echemus*, *Phyciodes phaon* and *Aphrissa neleis*) are found on Cuba but not on other islands of the Greater Antilles, three others (*Strymon martialis*, *Nathalis iole* and *Papilio andraemon*) are recorded only from Cayman, Cuba and Jamaica, but no Caymanian species appears to be shared exclusively with Jamaica.

Lack of isolation and a limited land area of rather uniform altitude and character have probably restrained the evolution of endemic species on the Cayman Islands (see also Scott 1972). Nevertheless, as described above, there are distinctive elements in the fauna of each of the Cayman Islands, and the following four subspecies are endemic: *Anaea echemus danieliana*, *Hemiargus ammon erembis* (accorded full specific status by some authorities, e.g. Clench 1964), *Brephidium exilis thompsoni* and *Papilio andraemon tailori*. The association between the Cuban and Cayman butterfly faunas is further emphasised by the presence in the Cayman Islands of several Cuban subspecies: *Danaus gilippus berenice*, *Anartia jatrophae guantanamo*, *Heliconius charitonius simulator*, *Hemiargus hanno filenus*, *Appias drusilla poeyi*, *Siproeta stelenes insularis*, *Battus polydamas cubensis*, *Papilio aristodemus temenes* and *Phocides pigmalion batabano*. A Jamaican influence in the Cayman Island fauna is perhaps seen in the occurrence of Jamaican forms of

Strymon acis (*gossei*) and *Panoquina sylvicola* (*woodruffi*) together with Cuban forms (*casai* and *sylvicola*, respectively) of the same species. The limited available material of *Dryas iulia* is ascribed (Riley 1975) to *D. i. carteri*, a subspecies found in the Bahamas.

Daily flight activity on Little Cayman

Butterflies were flying from soon after sunrise throughout the day to sunset, and two species not found on Little Cayman, *Cymaenes tripunctus* and *Anartia jatrophae*, were seen during darkness at lights (see above). Temperatures probably never drop sufficiently low to prevent flight, but the level of butterfly activity appears to alter through the day, being greatest in the morning. To quantify this impression, butterfly sightings on a transect at Pirates' Point, Little Cayman were counted at hourly intervals from 6.00 a.m. to 6.00 p.m. local time. The transect was triangular, running along a path north from the house to the road, thence east along the road beside the lagoon, and back to the house by another path, totalling approximately 300 m. It was covered in about ten minutes, walking very slowly. All butterflies seen were recorded but multiple recordings of the same individual on one transect were avoided as far as possible. The shade temperature was noted on completion of each transect. Observations were made on three days, July 16th, 17th and 20th, all in fine weather.

The totals of butterfly sightings on each transect are shown in fig. 28, together with the shade temperatures. Most individuals were recorded at 10.00 and 11.00 a.m., before maximum temperatures had been reached, and numbers were generally lower in the afternoons. In the twelve transects from 8.00 to 11.00 a.m., 141 butterflies were sighted, whereas only 90 were recorded between 1.00 and 4.00 p.m. On July 20th, however, when afternoon temperatures were especially high, more butterflies were recorded than on either of the other two afternoons (fig. 28), showing that high temperatures do not necessarily reduce butterfly flight activity. There is no overall correlation between temperature and the numbers of butterflies sighted considering the species either collectively or separately, but at eight of the thirteen transect times the numbers of butterflies varied directly with the temperature ($P < 0.001$). On this limited data it appears that there is a pattern of high activity in the morning and lower activity in the afternoon, but this pattern can be modified by temperature so that above average flight activity occurs when the temperature is above average at any particular time. Before conclusions can be reached, however, other climatic variables must be considered. The wind on all three days was light and rather variable; relative humidity was not measured.

A total of 263 sightings were made during the transects. This was composed as follows: 84 *Dione*, 74 *Anaea*, 48 *Ascia*, 15 *Strymon*, 10 *Euptoieta*, 8 *Leptotes/Hemiargus*, 6 *Panoquina*, 5 *Papilio*, 4 *Appias*, 4 *Heliconius*, 2 *Phoebis*, 2 *Eurema* and 1 *Junonia*. The three most numerous species showed rather different patterns of flight activity (fig. 29). In all there was reduced activity at noon, but whilst *Anaea* and *Dione* were active to some extent from sunrise to sunset,

Ascia ceased flying after 3.00 p.m. *Anaea* was almost equally active in the mornings and afternoons, as might be expected of a shade-loving species, but *Dione* was most frequent in the mornings and relatively few were seen flying in the afternoons.

Butterfly distribution on Little Cayman

The widespread distribution on Little Cayman of many of its butterfly species has already been commented on, and few species have narrow habitat requirements. To investigate further the distribution of butterflies, sightings of butterflies were counted during three transects into the interior of the island. The first transect was made on July 19th from the burnt-over coastal plantation of Bloody Bay southwards over the forty-two feet high ridge of old bluff limestone to the area of dwarf mangroves about half way across the island. Butterflies were counted on both the outgoing and return journeys. The second transect was on July 27th from the coast north of Sparrowhawk Hill southwards through the belt of coastal mangroves, across the ironshore plateau and over Sparrowhawk Hill onto the dissected bluff plateau eventually descending to the central forest. Butterflies were again counted on both outgoing and return journeys. The third transect, on August 1st, crossed the island from coast to coast. It commenced on the north coast at the western end of Crawl Bay and ran through a variety of habitats, including both ironshore and bluff formations, inland and coastal mangroves, to the south coast just west of Diggary's Point. The approximate lines of all three transects are indicated on the map (fig. 26).

The transects were all made in fine weather and between 8.00 a.m. and noon, the time when butterflies are usually most active (see above). Results in a condensed form are shown in table 21. Ten habitat types are recognised on the transects (described below table 21), and the mean number of each species of butterfly seen per five minutes in each of the ten habitats on the three transects has been calculated.

Butterflies were most frequent on the disturbed, often burnt-over, land of the old coconut plantations and beside the road on the coastal strip. In contrast, no butterflies at all were seen during the transects in the other coastal habitat, the sea-grape (*Coccoloba*) woodland. Mangrove swamps were also deficient in butterflies, none being noted in coastal mangroves and very few in inland mangroves. Most of the latter were probably encouraged to penetrate the mangrove areas by the traces cut by the Cadastral Survey. Only *Phocides* appears to be characteristic of mangroves. There appeared to be little difference between the butterfly faunas of comparable habitats on ironshore and bluff formations (cf. habitats 5 and 9; 6 and 10), the tree-clad north-facing slopes of the ridges of both being richer in butterflies than the more xerothermic scrub-covered plateaux. The central forest and its edge are intermediate between the two latter habitats in butterfly numbers.

As well as being the richest habitat in terms of butterfly numbers, the old coastal plantations and storm beaches also supported

Table 21. Numbers of butterflies counted per five minutes in each habitat zone on three transects of Little Cayman (see text)

	Habitats										Total individuals
	1	2	3	4	5	6	7	8	9	10	
Total time (mins.)	38	5	40	63	15	88	15	60	24	119	
<i>Anaea</i>	0.1	0	0	0.3	2.7	0.2	1.7	3.6	1.0	0.2	74
<i>Euptoieta</i>	2.8	0	0	0.2	0.7	0.1	0	0	0.2	0	28
<i>Junonia</i>	0.5	0	0	0	0	0	0	0	0	0	4
<i>Dione</i>	4.2	0	0	0.1	1.0	0.9	1.3	0.3	3.5	0.9	97
<i>Heliconius</i>	0	0	0	0	0	0.4	0.7	0.4	0.4	0.1	18
<i>Appias</i>	1.2	0	0	0.2	2.3	1.8	3.0	2.9	3.1	1.1	135
<i>Ascia</i>	1.1	0	0	0	0.3	0.1	0	0	0	0	11
<i>Eurema nicippe</i>	0.1	0	0	0	0	0	0	0	0	0	1
<i>E. lisa</i>	0.1	0	0	0	0	0	0	0	0	0	1
<i>Phoebis</i>	0	0	0	0	0	0.1	0	0	0	0	1
<i>Papilio</i>	0	0	0	0.1	3.0	0.3	1.7	1.0	0.6	0.2	40
<i>Strymon</i> spp.	0.1	0	0	0	0.3	0	0	0	0.2	0.1	6
<i>Leptotes</i>	0.3	0	0	0	0	0	0	0	0	0	2
<i>Hemiargus</i>	0.5	0	0	0	0	0	0	0	0	0	4
<i>Phocides</i>	0	0	0	0.1	0	0	0	0	0	0	1
All species	11.1	0	0	1.0	10.3	3.7	8.3	8.2	9.2	2.7	
Total individs.	84	0	0	12	31	65	25	98	44	64	423

Habitats :	Coastal strip - storm beach, old burnt-over plantations, road and verge	- 1
	- <i>Coccoloba</i> woods	- 2
	Mangrove swamps - coastal	- 3
	- inland	- 4
	Ironshore - north slopes of ridges with tall trees	- 5
	- plateaux with scrub	- 6
	- scrub/forest boundary zone	- 7
	- forest	- 8
	Bluff - north slopes of ridges with tall trees	- 9
	- dissected plateaux with scrub	- 10

the greatest number of species (table 21). Only *Papilio*, *Heliconius* and *Phocides* were not recorded from this region (*Phoebis* was quite frequently seen here at other times), *Euptoieta*, *Dione* and *Ascia* reached their greatest densities here, and *Junonia*, the *Eurema* species, *Hemiargus*, *Leptotes* and *Panoquina* are only found here.

Anaea is most prevalent where there are trees, being numerous in the central forest and common on the northern slopes of the ridges, although it is present in most habitats. *Dione* is also widespread but, in contrast to *Anaea*, it tends to be associated inland more with areas of scrub, being scarce in the central forest but more numerous than *Anaea* on the ironshore and bluff plateaux. *Heliconius* is more restricted in its distribution and is particularly characteristic of the forest edge, although it does penetrate onto the plateaux. Elsewhere it was observed flying at the edge of mangrove swamps adjacent to ironshore scrub. *Appias* is another insect associated especially with tall trees, although it is present in some numbers also on the plateaux and coastal strip. *Appias* differs from the other large, white Pierid, *Ascia*, in being more prevalent in inland localities. Probably all transect sightings of *Papilio* refer to *P. andraemon* which has a distribution rather like that of *Heliconius*, although it may be more tolerant of xerothermic conditions. The records of *Strymon* include two species, specimens from the coastal strip being *S. columella* and *S. martialis* and those inland all *S. martialis*.

Summary and Conclusions

The butterfly fauna of the Cayman Islands is unremarkable for its specific content or number of species, but the general abundance of butterflies is a feature of the islands. No endemic full species have been described in the islands' fauna of forty species, but four subspecies are known only from the Cayman Islands.

The Cayman fauna has its strongest affinity with that of Cuba, reflecting also a geographical relationship, but also present are some Jamaican elements. The majority of Caymanian butterflies has a distribution extending throughout the Greater Antilles. Even so, and notwithstanding the proximity of the Cayman Islands, the butterfly faunas of each of the three islands have a unique quality. This finds expression both in the appearance of some recognisably distinct island forms and in differences in the distribution and relative abundance of some species.

On Little Cayman, butterflies were active from soon after sunrise until sunset, although there are specific differences in flight activity. No overall correlation was found between flight activity and temperature, flight activity generally being greatest before noon.

The richest area faunistically on Little Cayman is the disturbed coastal strip. Most species are quite widely distributed over the island but three, *Papilio aristodemus*, *Nathalis iole* and *Phocides pigmalion*, may have narrower and more restricted environmental requirements. *N. iole* was taken only in the rather mesophytic area

about one kilometre north of Blossom Village, and *P. aristodemus* was found here and also further to the west on the ironshore north of the lagoon near Pirate's Point. Both of these areas are likely to be much altered by implementation of the 1975 development plan (alternative 2), and the butterflies could disappear from the island if they are, as appears to be the case, restricted to these places. Neither species is known from the other two Cayman Islands. The future of *P. pigmalion* seems to be more assured. It also is known only from Little Cayman and is associated with *Rhizophora*, albeit locally. It is plentiful at East Rocky Point, a region free of proposed development, and was sighted at other stations on the island.

Grand Cayman is the longest settled and most densely populated of the Cayman Islands. Its fauna does not appear to have been depleted, and is probably unchanged from the situation reported in 1938 by Carpenter and Lewis (1943). Since 1965 extensive mosquito control measures, including the spraying of insecticides, have been undertaken on Grand Cayman. These may have affected butterfly numbers on some parts of the island although, in general, there seemed to be little difference in butterfly numbers on the three Cayman Islands. Only six species found in 1938 were not noted in 1975 during the relatively brief stay on Grand Cayman and, in all probability, further study will reveal their continued existence. It appears that the butterfly fauna of the Cayman Islands is tolerant of some development, and several species are especially numerous in places where the land has been disturbed. It is important, however, that any development leaves unaltered large areas of all of the natural habitats in order to safeguard those species unable to adapt to a rapidly changing environment.

Acknowledgements

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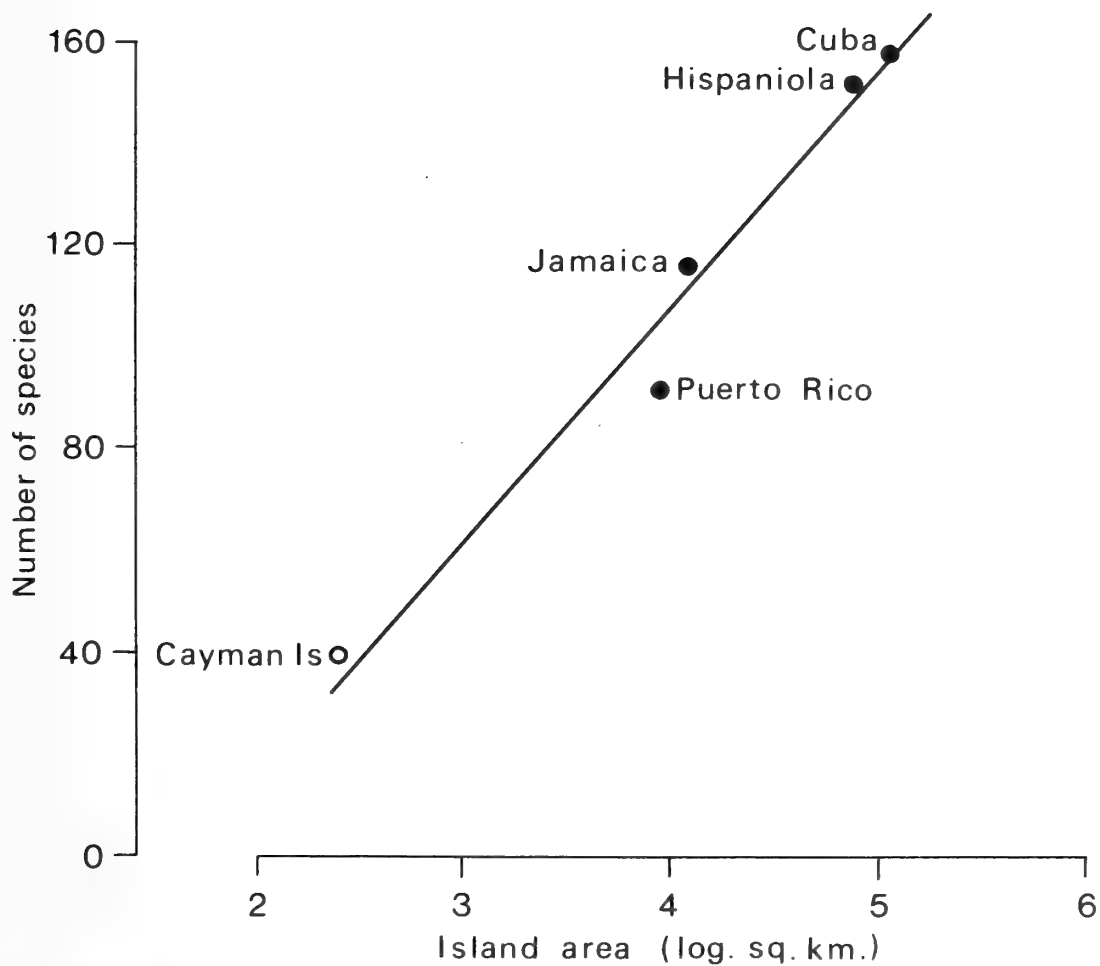


Figure 25. The relationship between the numbers of butterfly species and the areas (sq km on a logarithmic scale) of Cuba, Hispaniola, Puerto Rico, Jamaica, and the Cayman Islands ($r = 0.98$)

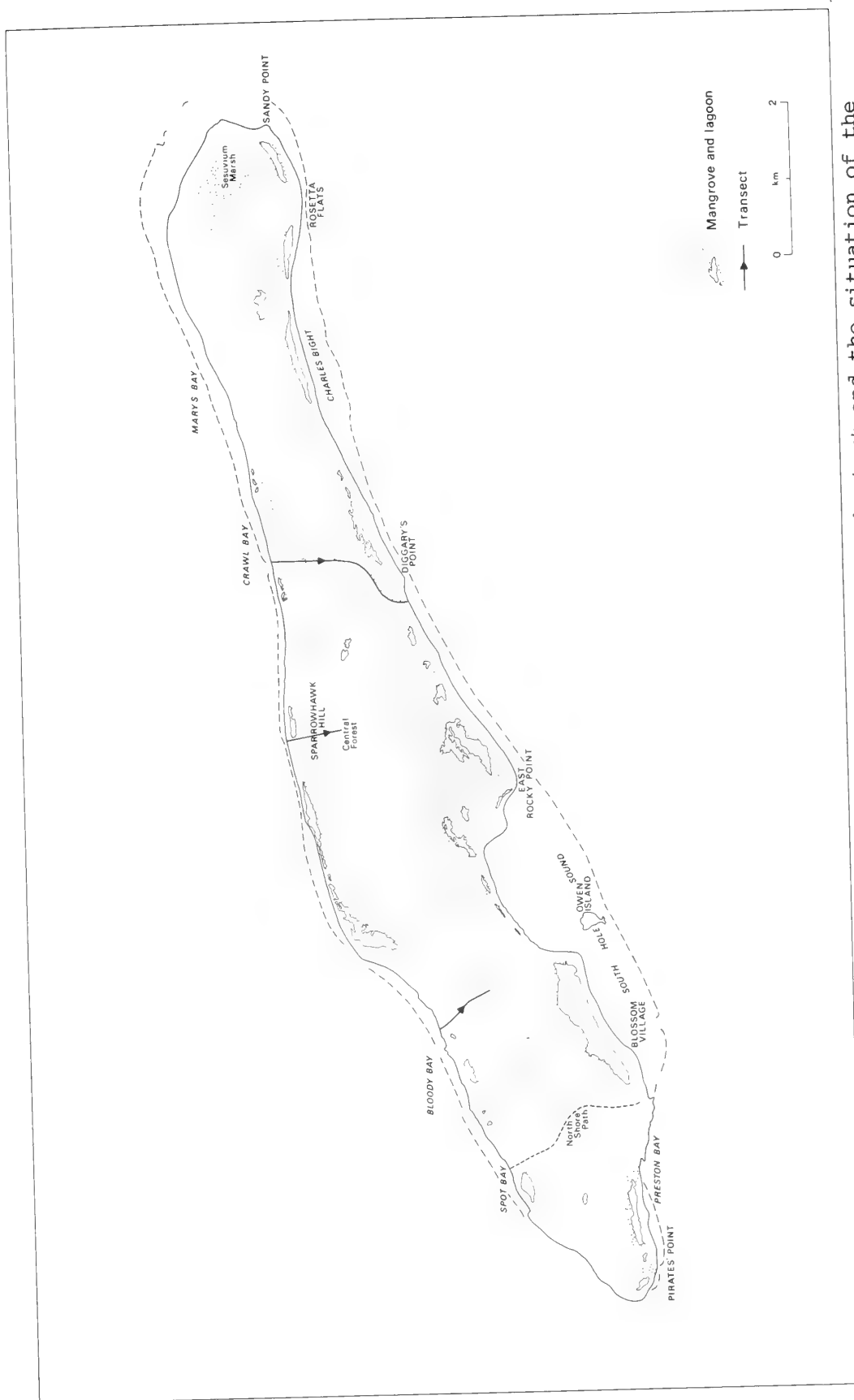


Figure 26. Map of Little Cayman showing localities mentioned in the text and the situation of the transects

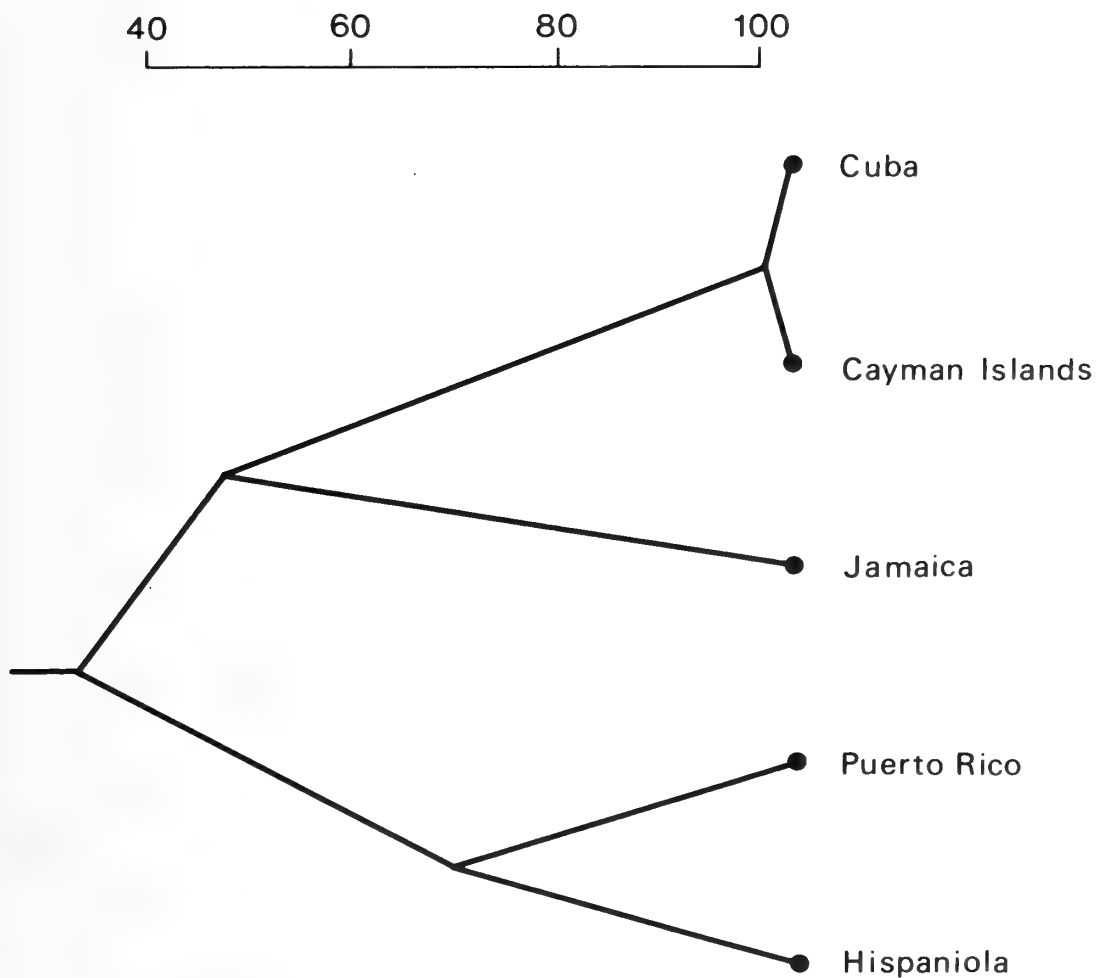


Figure 27. Associations between the butterfly faunas of the Greater Antilles based upon mean values of Cole's Coefficient of Association. The scale represents positive values of Cole's Coefficient

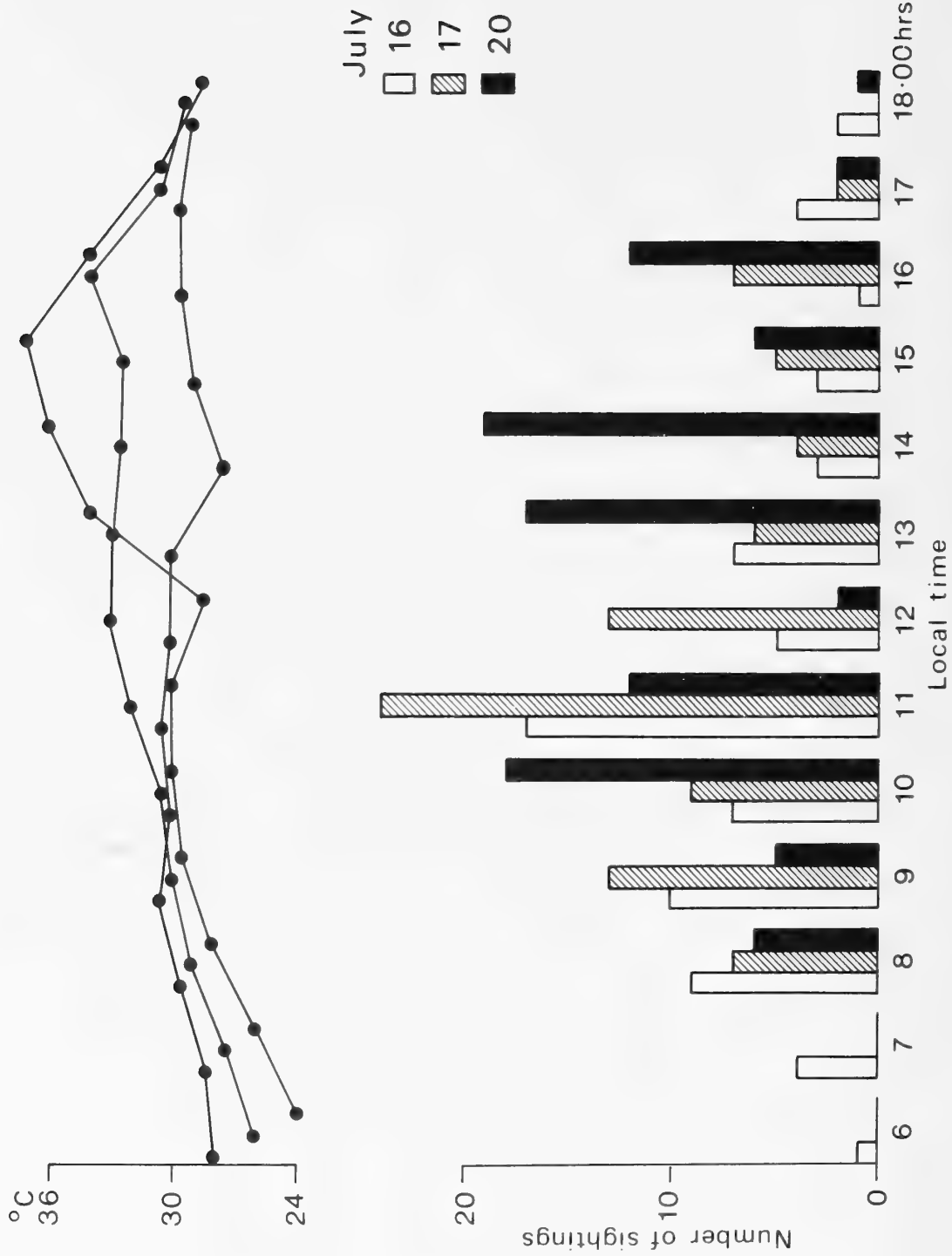


Figure 28. Numbers of butterflies sighted at hourly intervals (local time) during transects on three days at Pirate's Point, Little Cayman. Shade temperatures are shown above. For each hour the columns represent (from left to right) 16, 17 and 20 July

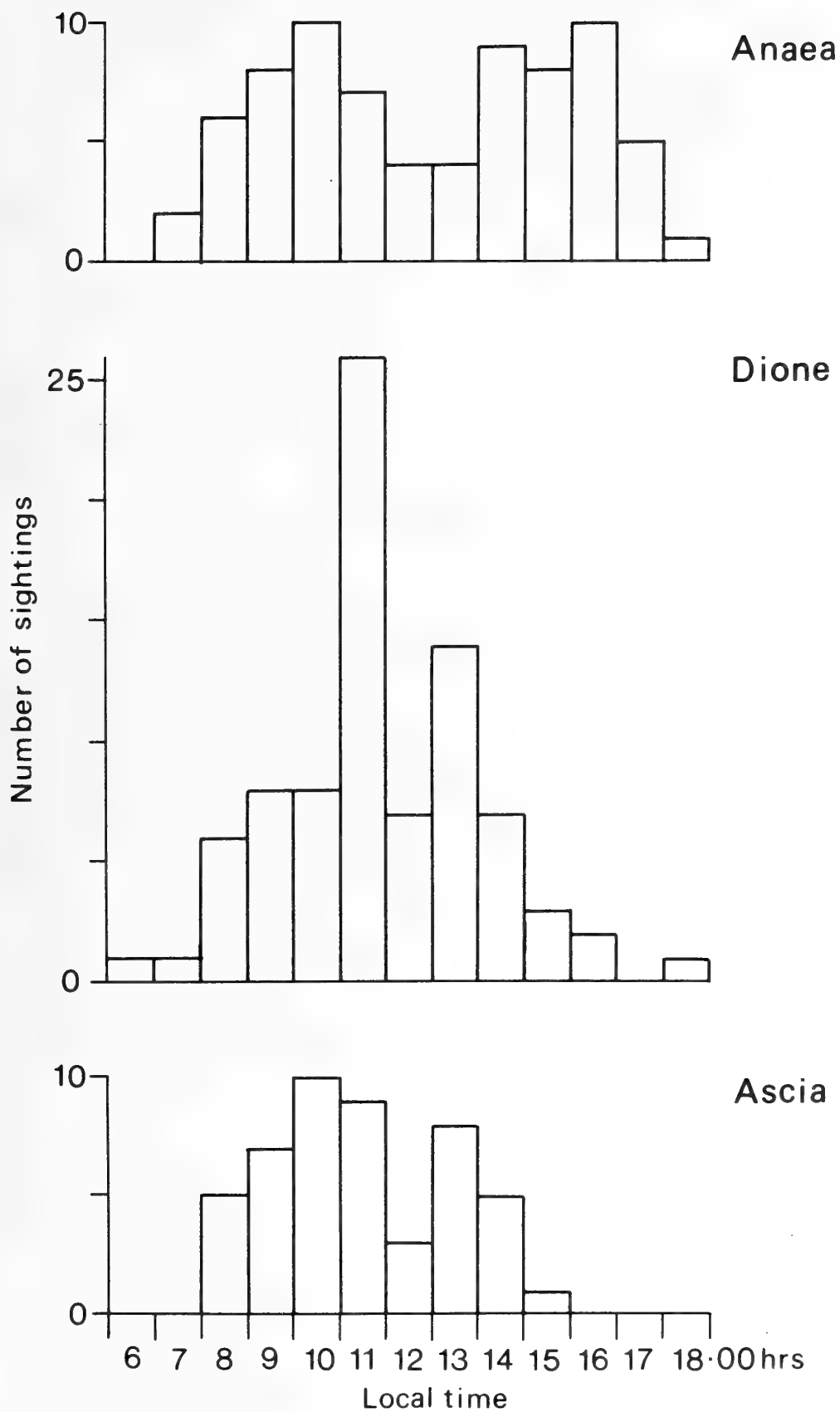


Figure 29. The hourly activity of *Anaea echemus*, *Dione vanillae* and *Ascia monuste* at Pirate's Point, Little Cayman

13. HAWKMOTHS (LEP., SPHINGIDAE) OF LITTLE CAYMAN

R.R. Askew

Little Cayman, for an island so small, supports a surprisingly rich hawkmoth fauna. Jordan (1940) records nineteen species found by the 1938 Oxford University Expedition to the Cayman Islands, five of which were taken on Little Cayman. In 1975 eleven species were captured on Little Cayman between 10th and 30th July, the majority being caught in a mercury vapour light trap operated at Pirate's Point (P) and, on the evening of 28th July, in the central forest south of Sparrowhawk Hill (F).

Species previously recorded (Jordan 1940) from Little Cayman

Xylophanes tersa (L.). 19P, 1F.
Agrius cingulata (F.). 2P.
Pseudosphinx tetrio (L.). 5P. Larvae feeding on *Plumeria obtusa* L.
(Frangipani).
Hyles lineata (F.). 1P.
Manduca brontes (Drury). 17P, of subspecies *cubensis* Grote.

Species newly recorded from Little Cayman

Manduca sexta (Johansson). 6P.
Errinyis ello (L.). 7P, 1F. Larvae on *Conocarpus*.
Aellopus tantalus (L.). 2, flying at dusk in F.
Eumorpha vitis (L.). 5P.
Madoryx pseudothyreus (Grote). 4P, 1F.
Cautethia grotei Edwards. 5P, 2OF. Of subspecies *hilaris* Jordan described from Cayman Brac.

Reference

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14. ECOLOGY AND SPECIES TURNOVER OF THE BIRDS OF LITTLE CAYMAN

A.W. Diamond

Introduction

The three Cayman Islands lie in the north-west Caribbean Sea, between Cuba and Jamaica. All are flat, low-lying limestone islands; the largest, Grand Cayman (185 sq. km) is about 117 km west of the two much smaller "lesser" Caymans, Little Cayman (24 sq. km) and Cayman Brac (31 sq. km). Little Cayman is the lowest of the group (maximum elevation 14 m) and is also the least disturbed by man. Human settlement is restricted to the immediate vicinity of the coast, chiefly in the south and west. Almost all the interior of the island is untouched by man, and had not previously been explored biologically. Most recent studies of island ecology and biogeography have been complicated by human disturbance, which introduces an unmeasured but undoubtedly significant factor into an island's ecology. On Little Cayman this effect is very slight, and the history and ecology of its avifauna are therefore of considerable scientific interest.

Previous work

The Cayman Islands were neglected ornithologically between the generally brief visits paid by the early collectors (Bangs 1916, Cory 1889, 1892, English 1916, Lowe 1911, Maynard 1889, Nicoll 1904, Townsend (in Ridgway 1887)) and the recent studies by Johnston and co-workers (Johnston, Blake and Buden 1971, Johnston 1975). All these workers, including the most recent, paid less attention to Little Cayman than to the other two islands. Johnston et.al. (1971) contains a number of unfortunate errors respecting both lesser Caymans, and Johnston (1975) refers chiefly to Grand Cayman and includes data from only 3 days spent on Little Cayman.

Previous workers on Little Cayman have necessarily been restricted to coastal habitats and the small areas of inland scrub woodland that were accessible from the footpaths then existing. In 1974, many narrow footpaths were cut all over the island to delimit plot boundaries, thus

making all the inland habitats accessible for the first time. It was therefore possible in 1975 to make the first thorough ornithological survey of the entire island, over a time period (9 July to 11 August) probably exceeding the total time spent by all previous ornithologists.

This paper is concerned chiefly with the ecology of the birds of Little Cayman, but it is helpful to consider the avifauna of the island first as a part of the Caymans as a group, i.e. in its West Indian context, and second in relation to the other two members of the group. Accordingly, the description of the ecological work that I carried out on the Royal Society and Cayman Islands Government Expedition to Little Cayman, is preceded by a brief analysis of the avifauna, supplementing the previous treatment by Johnston (1975).

The Cayman Island avifauna

(a) Derivation

The Cayman Islands lie more or less equidistant from Cuba and Jamaica, and about half as far again from Central America. These are therefore the most likely sources areas from which the Cayman avifauna has been derived. An analysis of the distribution of the species of land bird (pigeons to passerines) that breed in the Caymans (Tables 22 and 23) shows that their affinities are overwhelmingly West Indian rather than Central American; furthermore, most species occur also in the Greater Antilles, whence the predominant influence is Cuban and, to a much lesser extent, Jamaican. Many Cayman species do also occur in Central America, but all of these also occur in either Cuba or Jamaica (10 of the 14 occur in both) with the sole exception of *Vireo magister* which occurs on Grand Cayman and coastal Central America only. The single Lesser Antillean element in the avifauna is the flycatcher *Elaenia martinica*. The Cayman avifauna as a whole is thus predominantly Greater Antillean in affinities, with Cuba probably playing the major single role as a source area.

(b) Distinctiveness

Only one full species, the thrush *Mimocichla ravidia*, was endemic to the Caymans; it was restricted to Grand Cayman and may well now be extinct. However of the 28 landbird species that breed in the Caymans, no less than 15 species have forms, i.e. subspecies, that are endemic to the Caymans. Three of these — the parrot *Amazona leucocephala*, warbler *Dendroica vitellina* and grackle *Quiscalus niger* — have different forms on Grand Cayman from those on the "lesser" Caymans, making a total of 18 endemic forms (Table 23). The distribution of these forms is set out in Table 24. Clearly Grand Cayman has much the most distinctive avifauna, no less than 54% of its landbirds being endemic to the Caymans and 42% to Grand Cayman alone. The lesser Caymans are less distinctive, only Cayman Brac having an endemic form — the thrush *Mimocichla plumbea* — and the two islands together sharing only 3 endemic forms that are not also found on Grand Cayman (the parrot, warbler and grackle mentioned above). In addition, *Vireo magister* of Grand Cayman (and Central America) is replaced on the lesser Caymans by the very similar

Table 22. The species of land-birds breeding in the Cayman Islands, and their distribution elsewhere

	Central America	Cuba	Jamaica
White-crowned Pigeon <i>Columba leucocephala</i>	(isl)	X	X
Zenaida Dove <i>Zenaida aurita</i>	X	X	X
White-winged Dove <i>Zenaida asiatica</i>	X	X	X
White-bellied Dove <i>Leptotila jamaicensis</i>	(isl)	-	X
Ground Dove <i>Columbina passerina</i>	X	X	X
Cuban Parrot <i>Amazona leucocephala</i>	-	X	-
Mangrove Cuckoo <i>Coccyzus minor</i>	X	X	X
Smooth-billed Ani <i>Crotophaga ani</i>	(isl)	X	X
Barn Owl <i>Tyto alba</i>	X X	X	X
West Indian Nighthawk <i>Chordeiles gundlachii</i>	-	X	X
Flicker <i>Colaptes auratus</i>	-	X	-
W.I. Red-bellied Woodpecker <i>Centurus superciliaris</i>	-	X	-
Grey Kingbird <i>Tyrannus dominicensis</i>	-	X	X
Loggerhead Kingbird <i>Tyrannus caudifasciatus</i>	-	X	X
Stolid Flycatcher <i>Myiarchus stolidus</i>	-	X	X
Caribbean Elaenia <i>Elaenia martinica</i>	(isl)	-	- -
Northern Mockingbird <i>Mimus polyglottos</i>	-	X	X
Red-legged Thrush <i>Mimocichla plumbea</i>	-	X	-
Grand Cayman Thrush <i>Mimocichla ravidia*</i>	-	-	-
Thick-billed Vireo <i>Vireo crassirostris</i>	-	-	-
Black-whiskered Vireo <i>Vireo altiloquus</i>	(isl)	X	X
Yucatan Vireo <i>Vireo magister</i>	X	-	-
Yellow Warbler <i>Dendroica petechia</i>	X	X	X
Vitelline Warbler <i>Dendroica vitellina</i>	-	-	-
Bananaquit <i>Coereba flaveola</i>	X	-	X
Stripe-headed Tanager <i>Spindalis zena</i>	(isl)	X	X
Greater Antillean Grackle <i>Quiscalus niger</i>	-	X	X
Jamaican Oriole <i>Icterus leucopteryx*</i>	-	-	X
Yellow-faced Grassquit <i>Tiaris olivacea</i>	X	X	X
Cuban Bullfinch <i>Melopyrrha nigra</i>	-	X	-

(isl) = only on offshore islands, not on mainland.

* = probably extinct.

Table 23. Distributional affinities of the breeding land-birds of the Cayman Islands and Little Cayman.

Figures in brackets show number of Central American species that are restricted to offshore islands (see Table 21).

	<u>Cayman Islands</u>	<u>Little Cayman</u>
Central America (total)	14 (5)	12 (14)
Cuba (total)	22	14
Jamaica (total)	20	14
All three (total)	10	10
<hr/>		
Cuba + Jamaica (total)	17	14
Central America only	1	0
Cuba only	5	0
Jamaica only	5	0
Cuba + Jamaica only	7	5
Lesser Antilles (+ Central America isl.)	1	1

V. altiloquus, but this form is not a Cayman endemic.

The Cayman avifauna is thus very distinctive at a subspecific level; this is particularly noteworthy in view of the relatively short time for which these low, flat limestone islands can have been available for habitation by landbirds. This argues a rapid rate of evolutionary change on these very small oceanic islands. Later, I show that species turnover is also rapid in the Cayman avifauna, suggesting that if a newly-arrived species is to survive, it must adapt very quickly to the local conditions in order to build up a large enough population to avoid extinction; the high level of endemism, at a subspecific level, is consistent with this suggestion.

One of the most striking features of the Cayman avifauna is the complete absence of hummingbirds. Throughout the West Indies, low islands similar to the Caymans have two species of hummingbird, one large and one small (Lack 1976); the Caymans are the only known exceptions to this. Lack (1976) could suggest no reason for this; ecological unsuitability of the Caymans for hummingbirds is very unlikely to be the cause, since there is no obvious reason why the Caymans should be less suitable for hummingbirds than any of the other low-lying limestone islands of the Caribbean. Lack did not accept that the vagaries of long-distance dispersal could have played any part in the distribution of land-birds in the West Indies, but in this instance it is difficult to avoid this conclusion, as indeed it is in

Table 24. The endemic forms of Cayman Island land-birds, and the islands on which they breed.

Populations probably extinct are bracketed

- White-bellied Dove *Leptotila jamaicensis collaris*. G.C.
 Cuban Parrot *Amazona leucocephala caymanensis*. G.C.
 Cuban Parrot *Amazona leucocephala hesternæ*. C.B., (L.C.)
 Flicker *Colaptes auratus gundlachii*. G.C.
 West Indian Red-bellied Woodpecker *Centurus superciliaris caymanensis*. G.C.
 Loggerhead Kingbird *Tyrannus caudifasciatus caymanensis*. G.C., C.B., (L.C.)
 Caribbean Elaenia *Elaenia martinica caymanensis*. G.C., C.B., L.C.
 Red-legged Thrush *Mimocichla plumbea coryi*. C.B.
 Grand Cayman Thrush *Mimocichla ravidæ*. (G.C.)
 Yucatan Vireo *Vireo magister*. (G.C.)
 Vitelline Warbler *Dendroica vitellina vitellina*. G.C.
 Vitelline Warbler *Dendroica vitellina crawfordi*. C.B., L.C.
 Bananaquit *Coereba flaveola*. G.C., C.B., L.C.
 Stripe-headed Tanager *Spindalis zena salvini*. G.C.
 Greater Antillean Grackle *Quiscalus niger bangsi*. C.B., L.C.
 Greater Antillean Grackle *Quiscalus niger caymanensis*. G.C.
 Jamaican Oriole *Icterus leucopteryx bairdii*. (G.C.)
 Cuban Bullfinch *Melopyrrha nigra taylori*. G.C.
-

some other cases of bird distribution in the West Indies (Diamond 1973a).

The Little Cayman avifauna

Little Cayman has a depauperate avifauna in comparison to that of the Caymans as a whole, lacking an entire family — woodpeckers (Picidae) — and ten full species that breed, or have recently bred, elsewhere in the archipelago. Whether these species are missing because of ecological deficiencies on Little Cayman, or because of difficulties of dispersal, is difficult to judge. The fact that the Lesser Caymans have 5 forms that are not found in Grand Cayman, where they are replaced by related forms, could be interpreted from either viewpoint; these forms might have arrived in the Caymans from different sources, or they might have evolved differently, after a

single arrival, due to differences in the environments of the lesser Caymans and Grand Cayman. The much higher number of species in Grand Cayman, compared with the lesser Caymans, does suggest that it is richer ecologically (as would be expected from its larger size), since it is a similar distance from possible source areas as are the lesser Caymans.

Probably Little Cayman owes its impoverished landbird fauna chiefly to its ecological poverty; this takes the form not so much of a small variety of habitats as of the small extent and patchy distribution of habitats. Little Cayman probably has at least as many types of habitat as Cayman Brac, for example, but each is so small that it cannot support a distinctive avifauna. The only species that can survive there are therefore those of wide habitat tolerance, and with the ability to recolonise — in most cases probably from Cayman Brac, which is very near — after the local extinctions that seem to be a characteristic feature of the avifauna.

Ecology of the birds of Little Cayman

Objectives and methods

The objectives of the Royal Society and Cayman Islands Government Expedition to Little Cayman were to make as complete as possible a description of the biota of the island, and to make recommendations for its conservation and development. Within this context, the ornithological objectives can be summarised as follows:

- (1) to determine which species occur on Little Cayman, and their status;
- (2) to describe as fully as possible the ecology of each species, particularly in relation to habitat and food;
- (3) to draw attention to any species in need of special conservation measures;
- (4) to identify any habitat in need of special conservation measures because of its importance to birds.

The methods used were first, to define and map the habitats present, in conjunction with other members of the expedition (Stoddart 1979); second, to make systematic bird counts along transects (using cut paths) through each habitat. These counts were carried out before 09:00, i.e. when bird activity was at a maximum, using the methods of Lack (1976) in Jamaica and the Lesser Antilles and Diamond (1973a, unpub.) on St. Lucia, Martinique and Barbuda. This method served for terrestrial birds, but shore and sea birds were assessed differently. Non-systematic observations at coastal lagoons and on the sea shore were thought adequate to assess the status of shore birds and the scarcer seabirds; the large colony of Red-footed Boobies and Magnificent Frigatebirds was studied intensively and is described separately (Diamond 1979).

Results and discussion

(1) The species and their status

The species which have been recorded on Little Cayman are listed in the Systematic List (Appendix 1), which includes all published records to December 1975. The list includes 13 new records, definite breeding records for 13 species, and 21 species that are non-breeding migrants. The list is undoubtedly incomplete as regards North American migrants, but is probably complete for breeding species. Three species previously regarded as breeding residents — *Amazona leucocephala*, *Tyrannus caudifasciatus* and *Vireo crassirostris* — were certainly not breeding in 1975, and indeed of the three species the only record was a single distant view of a parrot. All are best regarded as extinct on Little Cayman, though probably the latter two were always sporadic breeders at best, for which local extinction on Little Cayman, with subsequent recolonisation from Cayman Brac, has been frequent. One waterbird, the Purple Gallinule *Porphyryula martinica*, has probably established itself as a breeding species in the last few years, and the Cattle Egret *Bubulcus ibis* colonised Grand Cayman in 1957 (Johnston et.al. 1971) and probably reached Little Cayman shortly thereafter. The Mockingbird *Mimus polyglottos* colonised sometime before 1966 and now thrives, but only along roads or around human settlements. This is the only one of the six species that have become established or extinct on Little Cayman since records began, in which the change of status can be attributed to man. The others all appear to involve natural species turnover and support the view that such turnover is a common phenomenon on small islands (MacArthur & Wilson 1963, 1967, MacArthur 1972, Diamond 1969, 1971, Diamond and Feare in press), rather than that turnover is rare and chiefly due to human influences (Lack 1976).

Species turnover on Grand Cayman and Cayman Brac was described by Johnston et.al. (1971). Unfortunately, all but one of the species that they listed as recent colonists, were not: *Phaethon lepturus*, *Sula leucogaster*, *Himantopus himantopus*, *Sterna albifrons*, *Hydranassa tricolor* and *Chordeiles minor* (= *C.gundlachii*) had all been recorded by the early workers. Nevertheless there have been real, documented changes in the avifauna, and these are set out in Table 25, which strongly suggests that species turnover is a regular feature of the avifauna of all three islands.

The numerical status of a species is difficult to estimate from a short visit at one time of year. The systematic list includes my personal assessment of the probable status of each species recorded on Little Cayman; these assessments are based on counts (Table 28) and breeding records (Table 27) for breeding land birds, and general experience in the West Indies, especially the neighbouring island of Jamaica, as well as the general works of Bond (1974) and Lack (1976), for other species. The abundance of island populations is likely to fluctuate considerably between years, and indeed species turnover is only the extreme case of fluctuation in population size.

Table 25. Distribution of Cayman Island endemic land-birds

Figures in brackets show totals before recent extinctions
(see Table 26)

	Total No. Breeding Species		No. Cayman endemics		No. island endemics	
Total, Cayman Islands	28	(30)	16	(18)	10	(12)
Grand Cayman	26	(28)	12	(14)	9	(11)
Cayman Brac	20	(21)	7		1	
Little Cayman	18	(21)	6		0	
All three	16		3		-	
Lesser Caymans, total	17	(18)	4		-	
Lesser Caymans, alone	1		3		-	

(2) Habitats, food and ecological segregation

The distribution of habitats, and the transects through them, are shown in Fig. 30. Habitats not included on transects were the beach ridge vegetation and the inland *Sesuvium* marsh which were, respectively, too narrow and too small in area for quantitative sampling.

Bird counts made in each habitat are summarised in Table 28. For comparison, a single count made in the tall forest on the high bluff on Cayman Brac, above Stake Bay, is also included. Table 28 shows that most species occurred in most habitats; exceptions were the two *Dendroica* warblers, the Yellow *D. petechia* occurring only in mangrove and the Vitelline *D. vitellina* in limestone vegetation, the two overlapping only inland dwarf mangrove; the White-crowned Pigeon *Columba leucocephala* which occurred chiefly in mangrove, the only habitat in which it was heard singing; the Ground Dove *Columbina passerina*, not found in mangrove; and the Black-whiskered Vireo *Vireo altiloquus* which was restricted to the vicinity of tall trees, although this is not apparent in Table 28. The two *Dendroica* warblers, though segregated by habitat, also differed in feeding height in a remarkable

Table 26. Extinctions and colonisations in the Cayman Island avifauna

<u>Island</u>	<u>Species extinct</u>	<u>Species colonised</u>	<u>Notes</u>
GRAND CAYMAN	<i>Mimocichla raveda</i>		Last seen 1938
	<i>Icterus leucopteryx</i>		Last seen 1938
		<i>Bubulcus ibis</i>	1st recorded 1957
		<i>Zenaida asiatica</i>	1st recorded ca.1935
CAYMAN BRAC	<i>Quiscalus niger</i>		absent 1970, 1971 (Johnston et.al.1971), 1971,1975(pers.obs.)
		<i>Bubulcus ibis</i>	Established 1957 or after
		<i>Zenaida asiatica</i>	Established presumably after 1935
		<i>Mimus polyglottos</i>	Date of arrival unknown
		<i>Leptotila jamaicensis</i>	Between 1971 and 1975
LITTLE CAYMAN	? <i>Amazona leucocephala</i>		see text — no good evidence ever bred
	<i>Tyrannus caudifasciatus</i>		see text — perhaps always sporadic
	<i>Vireo crassirostris</i>		Date unknown — see text
		<i>Bubulcus ibis</i>	1957 or after
		<i>Zenaida asiatica</i>	see Cayman Brac
		<i>Mimus polyglottos</i>	1st record ca. 1966
		<i>Porphyryula martinica</i>	post-1971

Table 27. Breeding records of Little Cayman birds, 9 July -
11 August 1975

<u>Species</u>	<u>Date</u>	<u>Description</u>
Common Stilt	24 July	Juvenile, unable to fly.
Common Stilt	25 July	2 fledgelings with 3 adults.
Ground Dove	16 July	Distraction display by empty nest scrape.
Ground Dove	16 July	1 very short-tailed juvenile seen.
West Indies Nighthawk	15 July	1 chick under <i>Tournefortia</i> bush.
West Indies Nighthawk	Late July	1 egg.
Grey Kingbird	16 July	Immature seen (very short-tailed).
Grey Kingbird	17 July	1 adult feeding 1 flying juvenile.
Caribbean Elaenia	13 July	Nest, 4.5 m in 7.6 m <i>Terminalia</i> tree;
Caribbean Elaenia	19 July	Same nest contained at least 2 large young.
Caribbean Elaenia	13 July	Nest, 2 young, 2.4 m in 3.0 m <i>Thrinax</i> tree.
Caribbean Elaenia	3 August	Nest, 5.4 m in 6.0 m <i>Coccoloba</i> tree, robbed (of egg(s)) by Grackle.
Caribbean Elaenia	3 August	Nest, 4.5 m in 4.8 m <i>Bursera</i> tree.
Black-whiskered Vireo	19 July	1 dependent juvenile with 1 adult.
Yellow Warbler	3 August	1 adult carrying nest material.
Yellow Warbler	6 August	2 dependent juveniles netted, Owen Island.
Vitelline Warbler	16 July	1 adult feeding 2 juveniles.
Vitelline Warbler	24 July	1 adult feeding 1 juvenile.
Vitelline Warbler	24 July	2 adults with 2 juveniles begging from them.
Bananaquit	24 July	1 juvenile begging from 1 adult.
Bananaquit	27 July	2 adults copulating.
Bananaquit	3 August	1 nest in <i>Myrcianthes fragrans</i> (Myrtaceae).
Bananaquit	4 August	1 adult carrying nest material.
Bananaquit	?	1 nest in <i>Bumelia glomerata</i> (Sapotaceae).
Greater Antillean	16 July	3/4 juveniles begging from adults.
" Grackle	19 July	2 juveniles begging from 2 adults; 1 adult fed a lizard to one.
"	24 July	1 adult carrying food to 1 juvenile.
"	3 August	1 adult feeding Elaenia egg to juvenile.
Yellow-faced Grassquit	26 July	Male carrying nest material.
Yellow-faced Grassquit	5 August	Male carrying nest material.

Table 28. Average number of birds per hour recorded in five habitats on Little Cayman

	closed woodland	open scrub	mixed scrub/ woodland	dwarf mangrove	tall mangrove		tall closed woodland, Cayman Brac
No. hours counting	2.0	3.0	3.9	2.3	0.7		0.7
White-crowned Pigeon <i>Columba leucocephala</i>	0	0.7	0	0.4	8.3		9.2
Zenaida Dove <i>Zenaida aurita</i>	5.5	5.6	3.8	0.9	1.4		15.4
White-winged Dove <i>Zenaida asiatica</i>	0	0	0.8	0	0	White-bellied Dove <i>Leptotila</i> <i>jamaicensis</i>	4.6
Ground Dove <i>Columbina passerina</i>	1.0	2.3	2.3	0	0		9.2
Mangrove Cuckoo <i>Coccyzus minor</i>	3.5	0	1.0	0	0		3.1
Grey Kingbird <i>Tyrannus dominicensis</i>	0	1.0	4.9	0.9	1.4		3.1
Caribbean Elaenia <i>Elaenia martinica</i>	24.5	16.3	17.4	3.9	11.1		32.3
Black-whiskered Vireo <i>Vireo altiloquus</i>	2.0	0.7	1.5	0	0		X
Yellow Warbler <i>Dendroica petechia</i>	0	0	0	1.3	6.9		0
Vitelline Warbler <i>Dendroica vitellina</i>	22.0	9.3	20.8	2.2	1.4		16.9
Bananaquit <i>Coereba flaveola</i>	11.5	11.3	5.1	4.8	6.9		1.5
Grackle <i>Quiscalis niger</i>	4.5	6.3	1.3	5.2	8.3		0
						Thick-billed Vireo <i>Vireo crassirostris</i>	9.2
						Yellow-faced Grassquit <i>Tiaris olivacea</i>	4.6
Number of species	8	9	10	8	8		12
Mean no. individuals/ hour	75	54	59	20	46		109

X = present, but not recorded in formal count.

Table 29. Habitats of breeding birds of Little Cayman

Includes probable breeders as well as those for which definite breeding records exist.

SPECIES	HABITAT								
	Exposed reef	Pools and lagoons	Cleared by man	Sand beach ridge	Scrub (open)	Scrub woodland (closed)	Dwarf mangrove	Tall mangrove	Sesuvium marsh
Pied-billed Grebe		U							
Red-footed Booby								VC	
Magnificent Frigatebird								U	
Green Heron	FC	FC							FC
Little Blue Heron	FC	FC						FC	
Cattle Egret			FC						
Snowy Egret	FC	FC						FC	FC
Tricoloured Heron	U	FC							
Yellow-crowned Night Heron		U		U					
West Indian Tree Duck		U							C
Common Guinea Fowl		U				U			
Purple Gallinule		U							U
Common Gallinule		FC							U
American Coot		FC							
Common Stilt		C							U
Willet		U							
Least Tern	U			U					
White-crowned Pigeon					U		U	VC	
Zenaida Dove					VC	VC	U	C	
White-winged Dove					U	U			
Common Ground Dove			C	U	C	U			
Mangrove Cuckoo					U	C			
Smooth-billed Ani			FC						
Barn Owl						U			
West Indian Nighthawk				FC				FC	
Grey Kingbird					C		U	FC	
Caribbean Elaenia			FC		VC	VC	FC	C	
Northern Mockingbird			FC						
Black-whiskered Vireo					U	FC			
Yellow Warbler							FC	C	
Vitelline Warbler					C	VC	FC	U	
Bananaquit			VC	C	VC	VC	FC	FC	
Greater Antillean Grackle			FC	U	FC	FC	FC	FC	
Yellow-faced Grassquit			C						

Notes: U = uncommon, FC = fairly common, C = common, VC = very common, as defined by Johnston (1975).

manner (Fig. 31). The almost complete segregation in feeding height between the two species is due only in part to differences in the height of vegetation in which they occur; this would explain why Yellow Warblers fed higher than Vitelline, since there were more tall mangroves than tall terrestrial trees, but not why almost no Yellow Warbler feeding took place between 2 and 4 metres. The samples are of course very small, but are nonetheless highly significant statistically ($\chi^2 = 28.6$, $p < .001$). Why the species should so segregate, when they already have almost completely different habitats, is very difficult to see; possibly at other seasons one moves more into the other's habitat.

Four species of essentially insectivorous small passerines occur widely, three of them overlapping considerably in habitat, and Table 30 shows that they feed in different ways. The two *Dendroica* warblers have already been discussed; the tyrannid flycatcher *Elaenia martinica* took more fruit than the others and also caught more of its insect food by flycatching, whereas the Bananaquit *Coereba flaveola* took a high proportion of nectar. The large tyrannid *Tyrannus dominicensis* might also have been included, but only 13 feeding observations were made, 11 of flycatching at about 6 m above ground and 2 of pouncing onto the ground — it takes presumably bigger insect prey, and certainly less fruit, than the *Elaenia*. Differences in feeding ecology seem to be rather more important than differences in habitat in maintaining ecological segregation on Little Cayman, probably because of the very limited range of habitats available.

The richest habitat in terms of individuals was closed scrub woodland on marl facies limestone, but slightly more species occurred in the intermediate scrub/scrub woodland area at the western end of the island. The dwarf and coastal mangroves contained about as many species as the limestone habitats, but very many fewer individuals. The tallest forest on Little Cayman, in the centre of the island south of Sparrowhawk Hill, was no different in either species composition or number of individuals from the surrounding woodland, and counts in the two habitats have been combined here. No habitat on Little Cayman approached the tall dense forest on Cayman Brac in numbers of either individuals or species (Table 28).

Not all habitats were counted systematically, but species found in each were recorded and these observations are summarised in Table 28.

(3) Species needing special conservation measures

The Vitelline Warbler *Dendroica vitellina* is the most distinctively Caymanian land-bird breeding on Little Cayman but in 1975 it was widespread and abundant there. It also occurs on both the other islands, where it is common (Johnston 1975). No special measures seem necessary for this or any other land-bird on Little Cayman.

Water-birds may be more threatened, since all stretches of open water are near the coast, where development is most likely. However unless complete drainage or filling, or large-scale pollution, are likely, sufficient area of open water should remain to maintain viable

Table 30. Feeding methods of 4 insectivorous passerines on Little Cayman

Species	n	Feeding method				
		Insects			Other	
		FL	GL	FL-GL	FRUIT	NECTAR
Caribbean Elaenia	40	35	30	12.5	22.5	0
Yellow Warbler	25	12	64	0	0	20
Vitelline Warbler	37	2.7	67.5	27	2.7	0
Bananaquit	25	0	28	0	0	72

Notes: n = number of feeding observations (maximum of 5 taken from one individual). FL = Flycatching; GL = gleaning; FL-GL = flycatcher-gleaning (as defined by Croxall (1977)).

Figures are percentage of observations (n) for each species.

populations of most water-birds. The *Sesuvium* marsh in the east of the island may prove to be an important breeding site for many of these species, especially the Tree Duck *Dendrocygna arborea*, and should be preserved both for its birds and for its intrinsic ecological interest.

The large colony of boobies and frigatebirds is described separately, but is mentioned briefly here as these are the species most in need of conservation measures; this is one of the largest, and surely the most accessible, of all West Indian seabird colonies. Necessary conservation measures include preservation of the mangroves in which both species nest, combined with maximum possible prevention of human and mechanical disturbance near the colony.

(4) Habitats needing special conservation measures

The mangroves comprising the booby and frigatebird colony have been identified (above) as the habitat of the species most in need of protection. No other single habitat is comparable in importance to bird life on Little Cayman. However it must be remembered that all the habitats on Little Cayman extend over small areas, so that destruction or disturbance of one habitat is likely to affect bird populations in others. In Section (2) it was shown that most land-birds occur in most habitats, and probably most individuals use many

of the habitats at one time or another. Hence it is ecologically unrealistic to approach the problem of conserving the avifauna in terms of individual habitats — the whole island needs to be considered as a single unit. It is in the almost completely undisturbed nature of the island as a whole that its chief biological interest lies, no more and no less for the birds than for any other biota. The scientific importance of an island that can be studied in an almost undisturbed state is already great, and will increase as more and more islands become developed. It may be unrealistic to propose that development on Little Cayman be restricted to its present level, but on biological grounds this is the course that must be recommended.

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Appendix 1. Systematic list

Nomenclature follows Lack (1976) for pigeons and passerines, Bond (1974) for remaining families.

Pied-billed Grebe *Podilymbus podiceps*. Regular in small numbers on some of the coastal lagoons, in breeding plumage. Probably a scarce breeding resident.

Brown Pelican *Pelecanus occidentalis*. Johnston et. al. (1971) describe this as an occasional visitor to all three islands, but the only definite record given is for Grand Cayman. Probably an occasional visitor.

Red-footed Booby *Sula sula*. The breeding colony of over 7,000 birds in the mangroves north and west of the lagoon behind Blossom Village is one of the largest in the Caribbean, and is described separately (Diamond 1979).

Anhinga *Anhinga anhinga*. 1 record, August 1971 (Johnston et.al. 1971).

Magnificent Frigatebird *Fregata magnificens*. Up to 20 pairs bred in the booby colony in 1971 (Diamond, unpub.). In 1975 they were not nesting, but the absence of adult males then suggests a breeding cycle with the same timing as elsewhere in the Caribbean (Diamond 1972, 1973b). Only flying immatures and adult females were seen, the maximum number seen together being 43.

Green Heron *Butorides virescens*. Regular in small numbers in the coastal lagoons and on the reef flats at low tide, and also common in the *Sesuvium* marsh inland. Probably a breeding resident.

Little Blue Heron *Florida caerulea*. Regular in small numbers around coastal lagoons. One immature seen. Probably a scarce breeding resident.

Cattle Egret *Bubulcus ibis*. Up to seven at the airstrip, feeding in short grass, in absence of cattle. Probably a scarce breeding resident, colonised within the last 20 years (Johnston et.al. 1971).

Snowy Egret *Egretta thula*. Regular in small numbers, in both coastal lagoons and reef flats at low tide. May breed.

Tricoloured Heron *Hydranassa tricolor*. Regular in coastal lagoons, and the commonest ardeid on the reef flat at low tide. Probably a breeding resident.

Yellow-crowned Night Heron. *Nyctanassa violacea*. Regular in coastal lagoons and on sea shore, especially at dusk. One immature seen; probably a fairly common breeding resident.

Glossy Ibis *Plegadis falcinellus*. One seen at airstrip, 24 July. No other records. Vagrant.

Roseate Flamingo *Phoenicopterus ruber*. 1 record, October 1970 (Johnston et.al. 1971). Vagrant.

West Indian Tree Duck *Dendrocygna arborea*. Occasional in coastal lagoons and over dwarf mangrove inland, but main concentration of up to 30 birds in *Sesuvium* marsh, where they fed in *Sesuvium* itself. May breed, probably resident.

Blue-winged Teal *Anas discors*. Recorded in October (Johnston et.al. 1971); probably a regular winter visitor.

Osprey *Pandion haliaetus*. Uncommon (Johnston et.al. 1971); probably a scarce but regular transient.

Merlin or Pigeon Hawk *Falco columbarius*. 1 record, February 1905 (Lowe 1911). Probably an occasional winter visitor.

Common Guinea Fowl *Numida meleagris*. Seen occasionally at edge of lagoon behind Pirate's Point. Presumably introduced.

Purple Gallinule *Porphyryla martinica*. Only 3 previous records for the Caymans, all from Grand Cayman (Johnston *et.al.* 1971). Regular, in small numbers, in coastal lagoons and in *Sesuvium* marsh, where a probable juvenile was seen. Probably breeds; evidently a recent colonist.

Common Gallinule *Gallinula chloropus*. Common in coastal lagoons, probably a breeding resident.

American Coot *Fulica americana*. Regular in small numbers in some coastal lagoons, especially at western end of island; probably a breeding resident.

Semipalmated Plover *Charadrius semipalmatus*. Seen regularly on muddy margins of coastal lagoons. Not previously recorded specifically for Little Cayman, though Lowe (1911) described it as "resident in the Caymans". Probably a regular migrant.

Thick-billed Plover *Charadrius wilsonia*. Seen regularly on muddy margins of coastal lagoons. No previous record. Probably a regular migrant.

Black-bellied Plover *Squatorola squatorola*. Seen in ones and twos in coastal lagoons and on sea shore. No previous records. Probably a regular migrant.

Ruddy Turnstone *Arenaria interpres*. Occasional in coastal lagoons. 1 previous record. Probably a regular migrant in small numbers.

Common Stilt *Himantopus himantopus*. A common breeding species of coastal lagoons; also recorded in *Sesuvium* swamp.

Spotted Sandpiper *Actitis macularia*. 2 seen on road, south-west coast, 26 July. Probably a regular winter visitor.

Greater Yellowlegs *Tringa melanoleuca*. Regular in small numbers in coastal lagoons. 1 previous record. Probably a common winter visitor.

Lesser Yellowlegs *Tringa flavipes*. Same status as *T. melanoleuca*; often seen together. No previous record.

Willet *Cataptrophorus semipalmatus*. Coastal lagoons; probably less than 20 birds in all. May breed, but no good evidence.

Least Sandpiper *Calidris minutilla*. Small numbers arrived with the following species on 24 July, in coastal lagoons. No previous record. Probably a regular migrant.

Semi-palmated Sandpiper *Calidris pusilla*. See preceding species. No previous record. Probably a regular visitor.

Sanderling *Crocethia alba*. 1 seen on south coast. No previous record. Probably a regular visitor.

American Dowitcher *Limnodromus griseus*. 2 seen with a single *L. scolopaceus* in the pool behind Pirate's Point, 12 to 14 July. No previous record. Probably a scarce migrant.

Long-billed Dowitcher *Limnodromus scolopaceus*. See preceding species. No previous record; probably a vagrant.

Laughing Gull *Larus atricilla*. 1 seen by Dr M.V. Hounscome. 1 previous record; probably an occasional visitor.

Gull-billed Tern *Geochelidon nilotica*. 2 adults, over west end of booby colony, 26 July. No previous record. Probably a vagrant.

Least Tern *Sterna albifrons*. One or two seen regularly along the south coast, including the lagoons. 1 dependent juvenile begging from 2 adults, 22 July, is not conclusive evidence of breeding because it might have flown from Cayman Brac. Probably a small resident breeding population.

Royal Tern *Thalasseus maximus*. 1 seen with 6 Least Terns, Owen Island, 25 July (Dr G. Potts). 1 previous record, October 1956 (Johnston et.al. 1971). Probably an occasional visitor.

White-crowned Pigeon *Columba leucocephala*. Commonest in mangrove, especially the tall coastal *Rhizophora*, the only place where song was heard. Substantial evening passage over East Point to Cayman Brac. Probably breeds, but most may do so on Cayman Brac.

Zenaida Dove *Zenaida aurita*. Common in all the limestone habitats, scarce in mangrove. Several times seen feeding on ground, occasionally apparently on *Bursera* fruits. Probably a breeding resident.

White-winged Dove *Zenaida asiatica*. Recorded only in the intermediate scrub/scrub woodland at west end, and scarce even there. Probably a breeding resident.

Common Ground Dove *Columbina passerina*. A fairly common breeding resident, found in all terrestrial habitats but not mangrove.

Cuban Parrot *Amazona leucocephala*. Only 1 record during the expedition, of a bird flying over the centre of the island, 27 July. May once have bred in large trees in the tall central forest, but probably not since the hurricane of 1935 destroyed the largest trees there, leaving no suitable nest sites.

Mangrove Cuckoo *Coccyzus minor*. Heard commonly in more closed limestone habitats. Not found in mangrove. Probably a breeding resident. Twice seen mobbed by small passerines, once by *Elaenia martinica* and once by *Quiscalus niger*.

Yellow-billed Cuckoo *Coccyzus americanus*. 2 records, August and October (Johnston et.al. 1971); probably a vagrant.

Smooth-billed Ani *Crotophaga ani*. A common breeding resident, restricted to beach-hedge vegetation and disturbed areas around houses and the airfield, where commonly seen in groups of up to 10, including immatures.

Barn Owl *Tyto alba*. Heard in tall central forest at night, by Dr M.V. Hounscome. Apparently very scarce on all these islands (Johnston et.al. 1971), but probably breeds.

Common or West Indies Nighthawk *Chordeiles gundlachii*. Apparently restricted to the coast, where 2 nests were found. Commonly seen feeding at dusk over the coast. A scarce breeding resident.

(Family Picidae. Woodpecker sp. Dr M.V. Hounscome heard a woodpecker drumming on 26 July but was unable to see the bird. There is no previous record of any woodpecker from either of the lesser Caymans, although two species breed on Grand Cayman.)

Yellow-bellied Sapsucker *Sphyrapicus varius*. "Uncommon winter visitor" (Johnston et.al. 1971); the characteristic holes made by this species were conspicuous in palm *Cocos nucifera* trunks on the coast.

Grey Kingbird *Tyrannus dominicensis*. Described by Johnston et.al. (1971) as a summer resident on all three islands. Commonest in the more open habitats of Little Cayman, absent from tall closed woodland (including mangrove); its habitats are very similar to those on Jamaica (Lack 1976). Only 13 feeding observations were made, 11 of flycatching at about 6 m, 2 of pouncing to the ground. Probably a summer visitor, as elsewhere in the north and western Caribbean (Bond 1974, Lack 1976).

Loggerhead Kingbird *Tyrannus caudifasciatus*. Described by Johnston et.al. (1971) as a "fairly common resident" on all the Caymans. I did not find it and queried its presence with Johnston who (in litt. 1975) confirmed that he saw only 1 on Little Cayman. Brown collected several on Little Cayman in 1911 (Bangs 1916), but neither Nicoll (1904) nor Lowe (1911) recorded it there in 1904. This species seems therefore to have been at best a sporadic inhabitant of Little Cayman.

Caribbean Elaenia *Elaenia martinica*. A very common breeding resident, the most conspicuous and widespread landbird on Little Cayman, especially in closed forest. The only positively identified food was the red berry of *Guapira discolor* (Nyctaginaceae), which was fruiting abundantly and was commonly taken by Elaenias.

Caribbean Martin *Progne dominicensis*. 1 recorded by expedition; no previous records. Probably an occasional visitor to all three islands.

Barn Swallow *Hirundo rustica*. Seen on about ten days during the expedition. 1 previous record, but probably a regular passage migrant.

Northern Mockingbird *Mimus polyglottos*. First recorded in 1966 (Johnston et.al. 1971), now established in the coastal areas inhabited or cleared by man, including the end of the road at Calabash Spot where one was heard singing.

Blue-gray Gnatcatcher *Polioptila caerulea*. 1 record (Cory 1889). Probably a vagrant.

Cedar Waxwing *Bombycilla cedrorum*. 1 record, April 1888 (Johnston et.al. 1971); vagrant.

Thick-billed Vireo *Vireo crassirostris*. Previously reported as a common breeding resident, and certainly collected by the early workers. Johnston (in.litt. 1975) did not see it in 1971, and nor did we in 1975 though it was common on Cayman Brac then. This species, like *Amazona leucocephala* and *Tyrannus caudifasciatus*, has evidently become extinct on Little Cayman since the early part of the century.

Black-whiskered Vireo *Vireo altiloquus*. A scarce but widespread bird on Little Cayman, probably breeding, and apparently confined to the vicinity of tall trees (ca. 8 m and over).

Black-and-White Warbler *Mniotilta varia*. 1 record (Lowe 1911), but probably a regular winter visitor.

Prothonotary Warbler *Protonotaria citrea*. 1 record, August 1961 (Johnston et.al. 1971); probably a vagrant.

Yellow Warbler *Dendroica petechia*. Common breeding resident, confined almost entirely to mangrove. Elsewhere in the West Indies, shows complex interactions with other *Dendroica* species, in some places being confined to coastal habitats by a sympatric congener in the forest inland (e.g. *D.adelaidae* on St. Lucia), moving into rain forest where no congener is present (e.g. Martinique), elsewhere coexisting with a congener in habitats similar to those on Little Cayman (e.g. *D.adelaidae* on Barbuda (pers.obs.)) — Diamond (1973a, Lack 1976). The Barbuda situation is most similar ecologically to that on Little Cayman, yet there *D.petechia* overlaps considerably in habitat with a congener, whereas on Little Cayman the two *Dendroica* species are strictly separated by habitat, at least in the summer — this situation would warrant further study.

Black-throated Blue Warbler *Dendroica caerulescens*. 1 record (Cory 1889); probably a scarce winter visitor.

Yellow-throated Warbler *Dendroica dominica*. Seen in mangroves 26 July and 2 August. 2 previous records. Probably a scarce passage migrant or winter visitor.

Blackpoll Warbler *Dendroica striata*. 1 record, August 1961 (Johnston et.al. 1971). Probably a vagrant.

Prairie Warbler *Dendroica discolor*. Recorded by Cory (1889) and Johnston et.al. (1971). Probably a regular winter visitor.

Vitelline Warbler *Dendroica vitellina*. This species is endemic to the Cayman and Swan Islands. Common throughout Little Cayman, except in mangrove. Breeding success was high in 1975; of the individuals whose age could be told in the field, 22 were adult and 17 juvenile, a proportion of 1.6 young per pair which is much higher than is usual in tropical passerines (c.f. 0.34 in Sarawak (Fogden 1972), 0.90 in Jamaica (Diamond 1974)). The juvenile plumage is sufficiently similar to the adult *Vireo crassirostris* to cause some initial confusion in the field, and is not described in the literature — olive grey above, pale eye-ring and superciliary, pale buff beneath. The ecological relationship between this species and the Yellow Warbler is described under *D.petechia* and in section 2 of the Results.

Palm Warbler *Dendroica palmarum*. 1 record (Cory 1889); probably a common winter visitor.

Ovenbird *Seiurus aurocapillus*. 1 record (Lowe 1911); probably a regular winter visitor.

Louisiana Waterthrush *Seiurus motacilla*. 1 netted and ringed, 30 July. No previous record, but probably a regular winter visitor.

Common Yellowthroat *Geothlypis trichas*. 1 record (Cory 1889), but probably a common winter visitor.

American Redstart *Setophaga ruticilla*. 1 record (Johnston et.al. 1971), but probably a regular winter visitor.

Bananaquit *Coereba flaveola*. A common and widespread breeding resident, in all habitats.

Greater Antillean Grackle *Quiscalus niger*. A common breeding resident, occurring in all habitats. Once seen taking an egg from a nest of *Elaenia martinica*.

Bobolink *Dolichonyx oryzivorus*. 1 record (Cory 1889); probably a regular spring passage migrant.

Yellow-faced Grassquit *Tiaris olivacea*. A common breeding resident, but confined to more open and disturbed coastal areas and roadsides.

Appendix 2. Ring number, weight, moult and breeding condition of land-birds ringed on Little Cayman, July - August 1975.

Ring	Species	Date	Age/Sex	Weight,g	Moult	Brood patch
Y 1	<i>Elaenia martinica</i>	19 July	F.G.	20.0	Early	-
Y 2	<i>Vireo altiloquus</i>	19 July	F.G.	20.25	Early	-
Y 3	<i>Coereba flaveola</i>	19 July	Ad.	10.75	Late	Present
Y 4	<i>Coereba flaveola</i>	19 July	Ad.	10.75	Late	-
Y 5	<i>Elaenia martinica</i>	19 July	F.G.	21.5	Early	-
Y 6	<i>Elaenia martinica</i>	19 July	F.G.	22.25	-	-
Y 7	<i>Elaenia martinica</i>	19 July	F.G.	22.75	Early	-
Y 8	<i>Elaenia martinica</i>	19 July	F.G.	20.0	Early	-
Y 9	<i>Coereba flaveola</i>	19 July	Ad.	12.25	Late	-
Y 10	<i>Coereba flaveola</i>	19 July	Juv.	-	Mid	-
Y 11	<i>Coereba flaveola</i>	19 July	Juv.	11.5	-	-
Y 12	<i>Coereba flaveola</i>	19 July	Juv.	8.75	-	-
B 1	<i>Columbina passerina</i>	19 July	F.G.	35.0	-	-
B 22	<i>Columbina passerina</i>	20 July	Imm	25.75	-	-
Y 13	<i>Elaenia martinica</i>	20 July	Ad.	27.0	Early	Present
Y 14	<i>Coereba flaveola</i>	20 July	Imm	9.75	-	-
Y 15	<i>Coereba flaveola</i>	20 July	Imm/Ad.	10.25	Late	-
Y 16	<i>Coereba flaveola</i>	20 July	Ad.	10.75	Late	-
Y 17	<i>Elaenia martinica</i>	20 July	F.G.	19.25	Early	-
Y 18	<i>Elaenia martinica</i>	20 July	F.G.	21.0	-	-
Y 19	<i>Coereba flaveola</i>	20 July	Ad.	10.5	Mid	-
B 3	<i>Columbina passerina</i>	20 July	Imm	24.5	-	-
B 4	<i>Columbina passerina</i>	20 July	Ad.	39.0	Mid	-
B 5	<i>Tyrannus dominicensis</i>	29 July	Ad.	-	-	-
Y 20	<i>Elaenia martinica</i>	29 July	Ad.	23.5	-	Present
Y 21	<i>Coereba flaveola</i>	30 July	Ad.	10.75	Complete	-
Y 22	<i>Elaenia martinica</i>	30 July	F.G.	20.5	-	-
Y 23	<i>Seiurus motacilla</i>	30 July	F.G.	18.0	Complete	-
Y 24	<i>Elaenia martinica</i>	30 July	F.G.	21.0	-	-
Y 25	<i>Coereba flaveola</i>	30 July	Juv.	9.0	-	-
Y 26	<i>Coereba flaveola</i>	30 July	Ad.	9.0	Late	-
-	<i>Elaenia martinica</i>	6 August	F.G.	19.5	Early	-
-	<i>Dendroica petechia</i>	6 August	Ad.M.	11.25	Early	-
-	<i>Dendroica petechia</i>	6 August	Juv.F.	11.0	-	-
-	<i>Dendroica petechia</i>	6 August	Juv.M.	11.5	-	-

Notes: Rings were plastic, coloured, Y = yellow, B = blue. All netted at Pirate's Point except those on 6 August, netted on Owen Island.

F.G. = full grown; Ad. = adult; Juv. = juvenile; Imm. = immature; Imm/Ad. = moulting from Imm. to Ad. plumage; M = male; F = female.

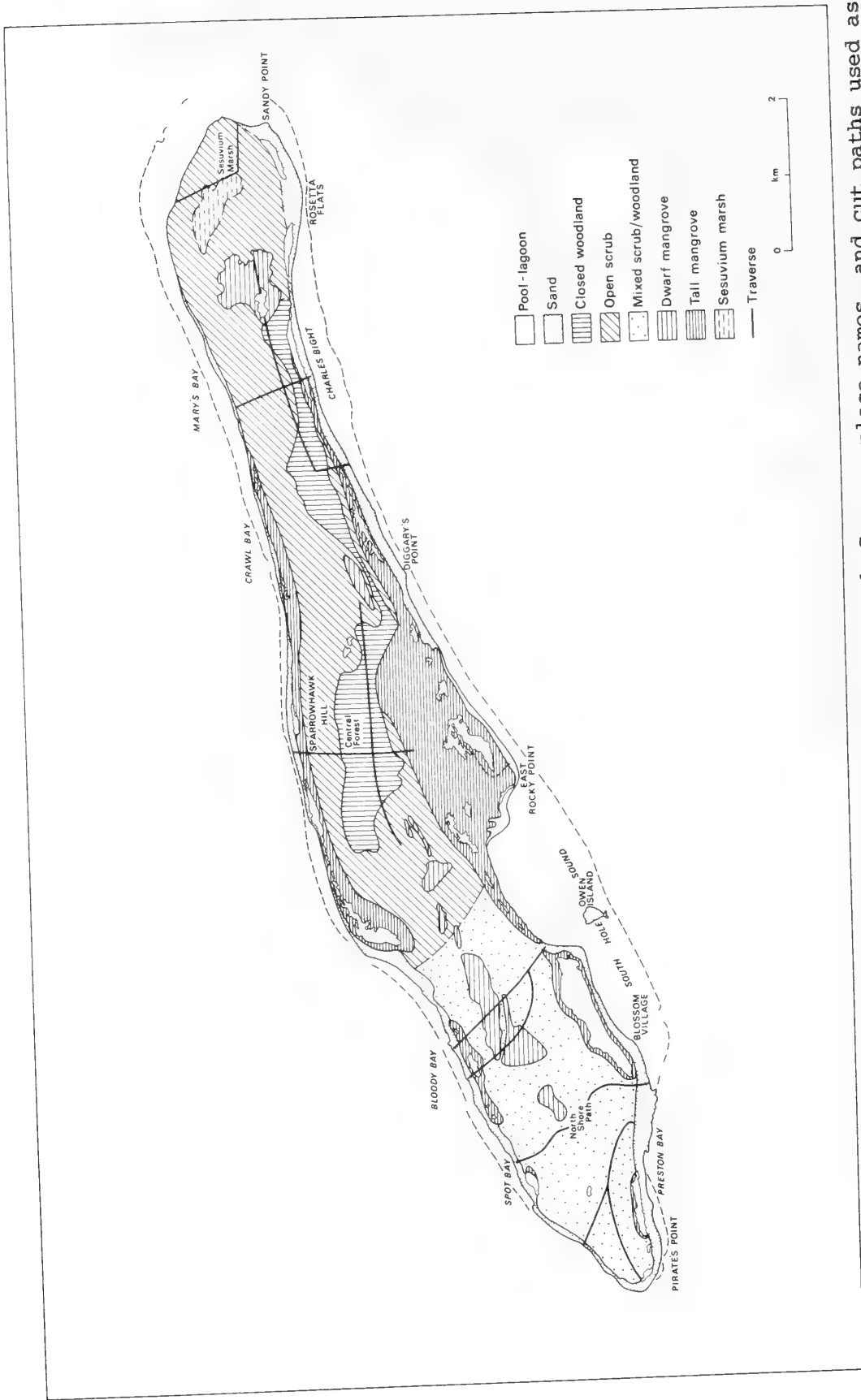


Figure 30. Map showing location of the main habitats on Little Cayman, place names, and cut paths used as transects

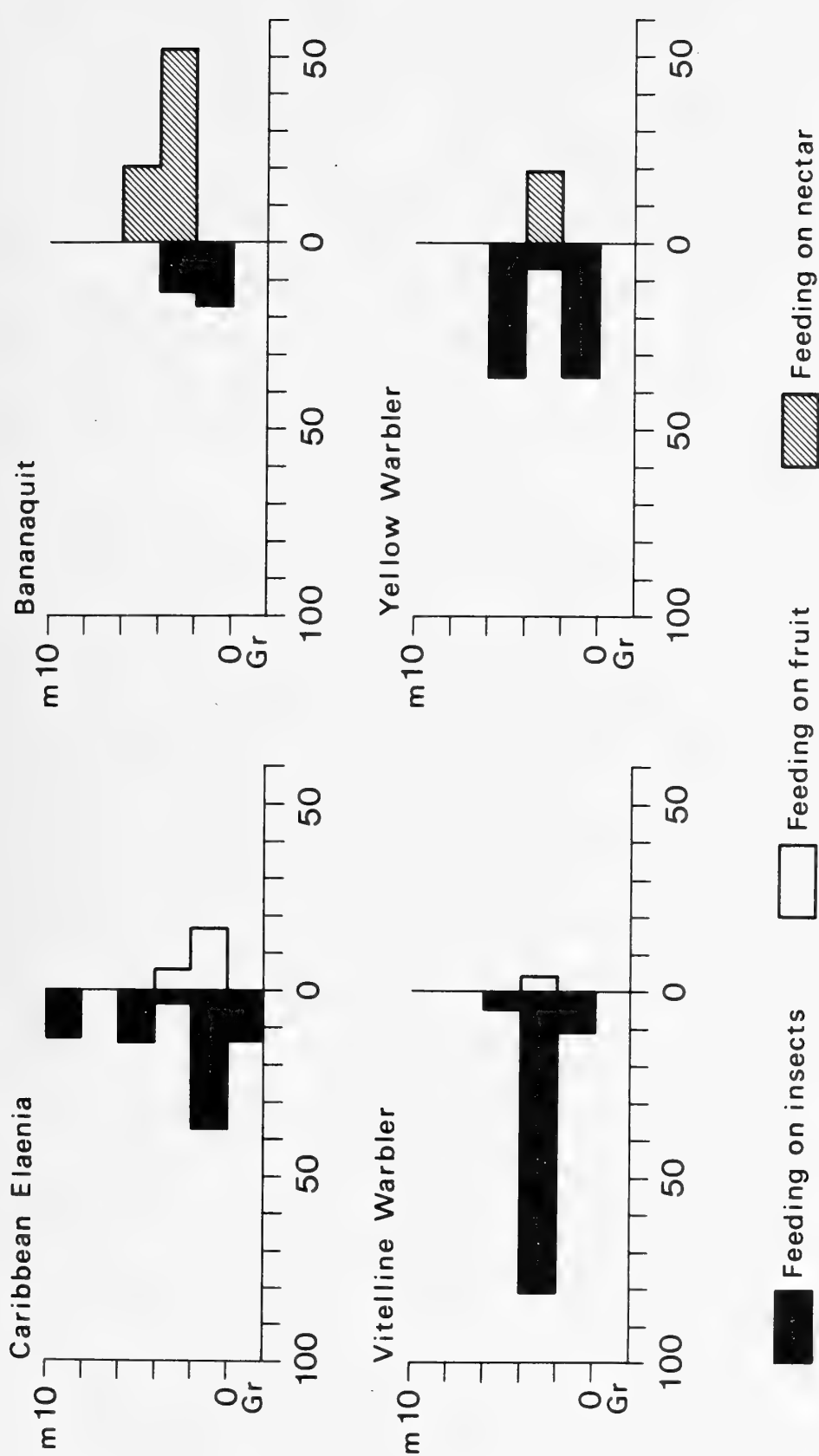


Figure 31. Feeding heights of four insectivorous passerines on Little Cayman: (a) Caribbean Elaenia; (b) Bananaquit; (c) Vitelline Warbler; (d) Yellow Warbler. Ordinate: height in intervals of 2 m (Gr = ground). Abscissa: percentage of feeding observations in each height class. White areas (right of 0%): feeds on fruit (Elania, Vitelline Warbler) or nectar (Bananaquit, Yellow Warbler). Black areas (left of 0%): feeds on insects. For sample sizes, see Table 29

15. THE RED-FOOTED BOOBY COLONY ON LITTLE CAYMAN:
SIZE, STRUCTURE AND SIGNIFICANCE

A.W. Diamond

The boobies of Little Cayman were described by Maynard (1889) as a new species, Cory's Gannet *Sula coryi*; at that time the plumage sequences and morphs of the Red-footed Booby *Sula sula* were not understood, and Maynard mistook the brown-morph adults for young birds. In many populations of *Sula sula* the adults are dimorphic, being either white with dark primaries and secondaries, or generally brown with white rump, tail and vent. The colour pattern of the brown morph varies geographically; those on Little Cayman, which constitute nearly 90% of the population, are generally brown except for the tail, rump, vent and sometimes the scapulars, which are white. Immatures are wholly brown, including the tail, rump and vent, and can always be distinguished from brown-morph adults by the dark bill and the pale orange, not deep red, legs and feet.

The colony on Little Cayman is one of the largest in the Caribbean, and is of special value because it is so accessible; more than any other seabird colony in the West Indies it has great potential, properly managed, both as a tourist attraction and for scientific research. The objectives of this short study were to estimate the size of the population, the proportions of juveniles and of the two adult colour-morphs, and to advise on possible interactions between the booby colony and the oil terminal that it is proposed to build on the island.

Location of the colony

Figure 32 shows the present location of the colony, and also the approximate positions it is known to have occupied in the past. When Maynard (1889) visited Little Cayman in 1888, the colony was chiefly in sea-grape trees *Coccoloba uvifera* between the sea and a coconut plantation, extending to landward partly into what is now the lagoon, but is now a mangrove swamp, immediately north of the settlement at Blossom Village (position 2, Figure 32). Maynard was told that the

boobies "had formerly occupied a small key, containing about three acres, that lay just opposite the present gannetry, a few hundred yards from the shore; but this spot was burnt over, some thirty years ago, when the birds all removed to the section now occupied by them". The approximate location of this former colony is numbered 1 on Figure 32.

This second colony did not stay long, for by the time Nicoll (1908) visited the island in 1904, the boobies were nesting in the mangrove swamp itself (position 3, Figure 32). In 1935, a hurricane destroyed most of these mangrove trees, whose roots still scatter the shallow lagoon there. The booby colony is now situated in the low mangroves that fringe the northern border of this lagoon, between the open water and the dry limestone scrub woodland behind (positions A to F, Figure 32).

The limits of the present colony were determined partly by inspection from the south side of the lagoon, partly by exploration on foot within the mangroves, and partly by inspection and photography from the air. The birds had finished breeding some time before, so strictly speaking it was the roosting area, rather than the nesting colony, that was delimited. However I did visit the colony briefly in 1971, when the boobies were nesting, and found then that they nested in the same areas as they were roosting in 1975.

Size of the colony

Census method Birds on the southern edge of the colony were clearly visible from the opposite shore of the lagoon and were counted from there, with 8 x 30 binoculars, between 0800 and 1000 on 1st August 1975. These counts, divided into sections delimited by easily identified landmarks, are given in Table 31. Birds not visible in this way, were estimated by two direct counts made on foot in quadrats within the mangroves, one of 23 birds in about 550 m² and one of 8 birds in about 150 m²; both these were underestimates because some birds flew off when they were approached, but every effort was made to reduce this bias to a minimum. The total area of mangrove occupied by the colony was then calculated by tracing the area of the colony from a 1:5,000 map onto graph paper and summing the area covered. The calculation of the population size was as follows:

(i) Birds visible on the edge This is simply the sum of the counts for each section, A to F, of the southern boundary of the colony, as in Table 30: Total 1,670.

(ii) Birds not so visible Total counted in two sample areas = 31 birds in 700 m². Total area occupied by colony = 45,575 m².
Therefore total number of birds = $\frac{45,575 \times 31}{700} = \underline{2,018}$.

(iii) Combined total 1,670 + 2,018 = 3,688

(iv) Correction for time of day The number of birds present in the colony changed markedly with the time of day. It was not possible to determine whether there was any time at which all the birds were

Table 31. Census of boobies along southern edge of colony, 0800 - 1000,
1 August 1975

Sections as in Figure 32.

Section	Total	Brown morph adult	White morph adult	Juvenile
A	181	86	15	15
B	327	81	31	52
C	560	122	35	35
D	440	49	32	20
E*	117	-	17	-
F	45	15	3	5
TOTAL	1,670	353	133	127

*Section E was too distant to distinguish between brown-morph adults and juveniles.

present; if this happens at all, it is probably at night. The best estimate was therefore to take the count at the time at which the maximum number was present, divide this by the number present at the time the census was carried out (these counts being carried out in a small area on 30 July, every hour throughout the day - Figure 33), and multiply the census figure by this factor. The maximum number was 241 at 0600, and the average number during the time of day the census was carried out (0800 - 1000) was 124. Accordingly the total in (iii) should be multiplied by $\frac{241}{124}$; $3,688 \times \frac{241}{124} = \underline{\underline{7,168}}$.

This calculation includes two sources of low bias: (i) some birds in the mangrove quadrats flew off before they could be counted; (ii) the figure of 241 birds in the sample area at 0600 is not a true maximum, since some birds were seen leaving the colony before it was light enough to count. The total of over 7,100 birds is therefore a minimum.

Composition of the colony

Three classes of booby could be distinguished easily in the colony: juveniles; brown-morph adults; and white-morph adults. The latter category could always be distinguished from the first two, but these two were not always distinguishable from each other.

(i) White morphs During the census of 1,670 birds on the colony edge, 133 white morphs were seen. Assuming that the proportion of white morphs was the same elsewhere in the colony, the total number of white adults in the colony = $\frac{133}{1,670} \times 7,168 = 571$ or 8% of the total population (including juveniles).

(ii) Brown morphs Of the $1,670 - 133 = 1,537$ "brown" birds (i.e. brown morph adults plus juveniles) counted during the census, only 480 could be identified positively as either adult or juvenile. Of these, 353 were adults and 127 were juveniles. Applying these proportions to the colony as a whole, the total number of brown morph adults in the colony is estimated as follows:

Total no. birds less total no. white morphs = $7,168 - 571 = 6,597$.

Proportion of brown morph adults, from above, is $\frac{353}{480} = 73.5\%$

Total number of brown morph adults is therefore $6,597 \times .735 = 4,852$.

The proportion of brown morphs in the adult population is therefore $\frac{4,852}{5,423} = 89.5\%$.

(iii) Juveniles The number of juveniles is the number of brown birds less the number already estimated as brown morph adults, i.e. $6,597 - 4,852 = 1,745$, or 24.3% of the total population of the colony.

An independent method of assessing these proportions was by counting the birds entering and leaving the colony in flight lines overland. This was done from the main jetty in Blossom Village on 30th July and 1st August; birds were counted for ten minutes in each hour from 0620 to 1830. The totals seen were: 625 brown morph adults, 70 white morph adults, 198 juveniles. Brown morph adults were here 89.9% of the adult population, *c.f.* 89.5% from the census figures; and juveniles were 22.2% of the whole population, *c.f.* 24.3% in the census.

The census of the colony, and its composition, can be used to estimate the approximate breeding population. The breeding season on Little Cayman is probably similar to that on Half Moon Cay, British Honduras, where Verner (1961) found it to be from November to April. When I visited Little Cayman briefly in February 1971, many birds had young in the nest, and in July-August 1975 there were no occupied nests but a great many recently-fledged juveniles. These observations are consistent with a November-April breeding season.

The number of flying young — i.e. birds produced in the breeding season immediately preceding my visit in 1975 — can be used to estimate the breeding population, given a knowledge of the breeding success. Unfortunately this is not known, but it must be less than 100%, so the population must be more than the 1,745 pairs needed to produce the 1,745 juveniles counted. Alternatively, one can assume that all the adults counted were breeders, in which case the number of breeding pairs

is half the number of adults, i.e. $\frac{5,423}{2} = 2,712$ pairs. These two

figures represent, respectively, the minimum and maximum likely breeding population, which is likely to lie nearer the maximum figure than the minimum, i.e. it is almost certainly over 2,000 pairs. The only other Caribbean colony of this species that has been counted is Half Moon Cay, where Verner (1961) counted 1,389 occupied nests.

Development implications

Effect of development on boobies

The present pattern of development on Little Cayman has probably had little effect on the boobies. The birds appear to be disturbed by people very little, if at all. However the proposed construction of an oil terminal in the area immediately behind the colony will inevitably result not only in destruction of the habitat immediately adjacent to the colony, but in a greatly increased level of general disturbance, both human and mechanical. There is little evidence that can be used to predict the effect on the birds, but it is very likely that they would be disturbed sufficiently at least to interfere with breeding success, and possibly to desert the colony altogether.

Effect of boobies on development

The present flightlines of the boobies between the colony and the sea are chiefly over Blossom Village, at the east end of the lagoon, and at the west end near the airstrip (Figure 32). Increased development will mean increased air traffic and probably larger aircraft; the presence of a booby flightline across the end of the airstrip will constitute a bird-strike hazard of major proportions. An adult booby weighs about 1 kg and flies into the colony probably at about 60 kph; it would certainly cause considerable damage to any aircraft that struck it. Although most birds enter and leave the colony within a couple of hours of dawn and dusk, there is some activity on the flightlines throughout the day.

In addition to the bird-strike hazard that it represents, the booby colony should constitute a constraint on development for other reasons. It is one of the largest seabird colonies in the Caribbean, and probably the most accessible; properly managed it could generate considerable revenue from tourism, and as a site for scientific research.

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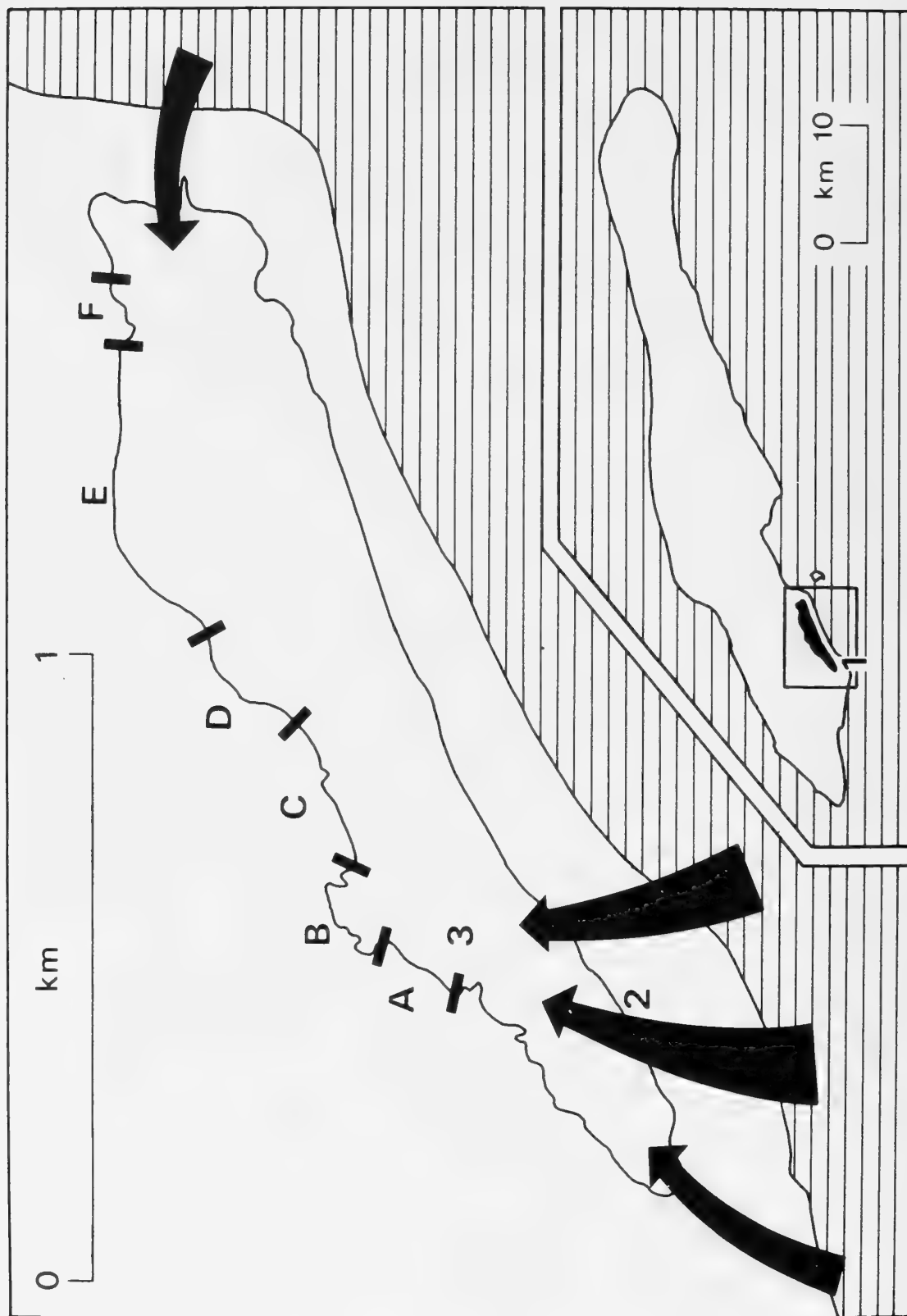


Figure 32. Outline map of Little Cayman, showing the location of the booby colony and detail of the colony area. Numerals refer to previous sites of the colony (see text). Letters represent sections of the present colony used in the census (see Table 30). Arrows represent main flight lines

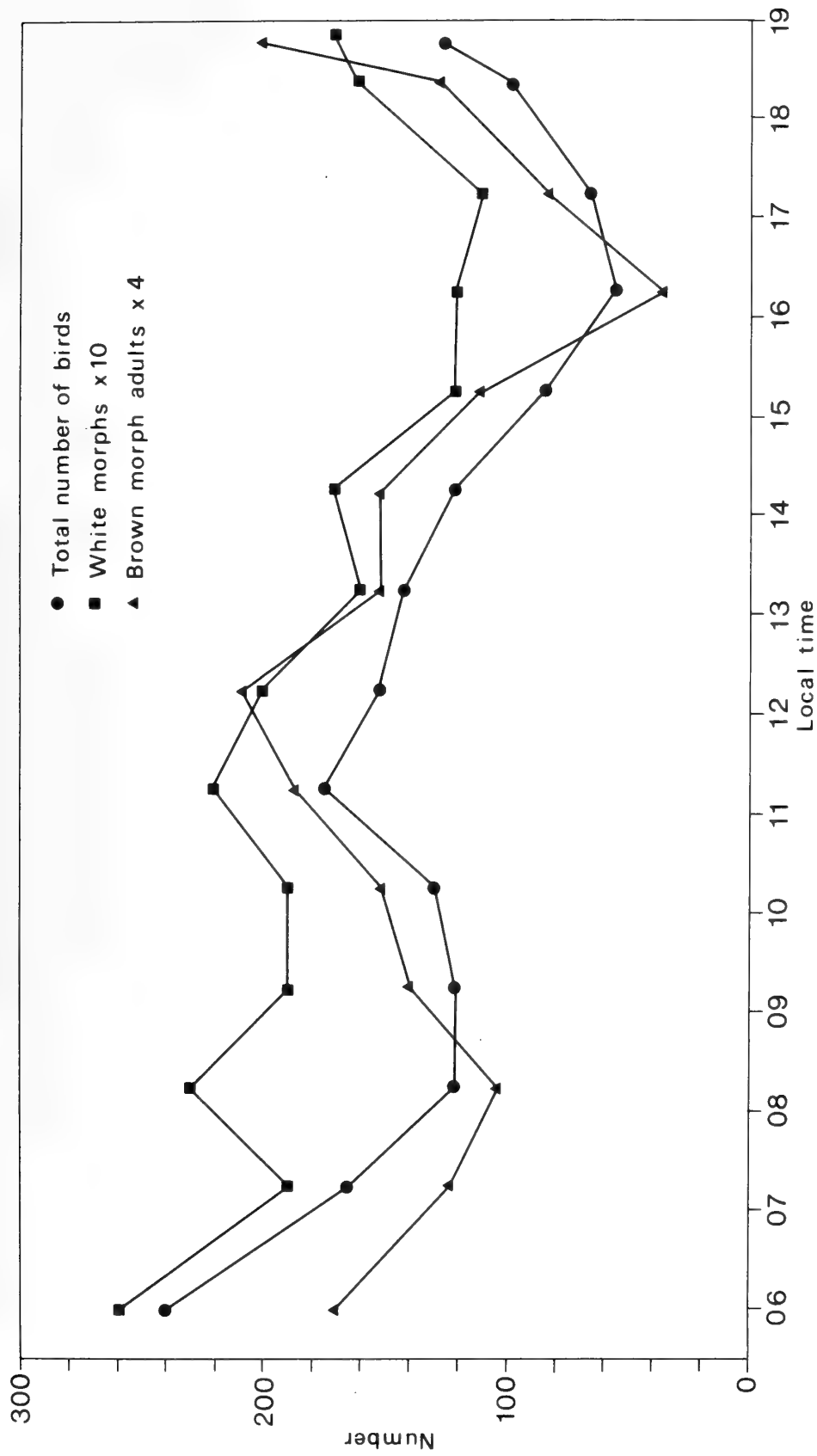


Figure 33. Diurnal variation in number of boobies present in the sample area of the colony

16. LITTLE CAYMAN: ECOLOGY AND SIGNIFICANCE

D.R. Stoddart

Introduction

In this final paper I wish to emphasize some of the conclusions drawn by contributors to this report, consider some of the gaps in our knowledge of the ecology of Little Cayman, and place what we now know of the fauna and flora in a wider Caribbean context. The purpose of this Expedition has been to provide the Cayman Islands Government, and through them the wider scientific community, with basic data on which future development proposals can be evaluated. It is not the purpose of this concluding discussion to comment on any particular set of development proposals, but it is nevertheless possible to draw attention to aspects of the ecology of Little Cayman which are of high intrinsic importance and which are also potentially at risk of disturbance or destruction.

The fauna of the Cayman Islands is dominantly Greater Antillean, and especially Cuban, in its relationships and derivation. This is now well-documented for the insects, especially the butterflies (H.K. Clench 1964, Scott 1972, Askew, this volume), and the land birds (Diamond, this volume), in both cases the main affinity being with Cuba and to a lesser extent with Jamaica. Similarly the reptiles are of Cuban (*Anolis*, *Cyclura*) or Jamaican (*Aristelliger*, *Diploglossus*, *Sphaerodactylus*, *Alsophis*, *Tropidophis*) affinity (Grant 1940, Savage 1966, Schwartz and Thomas 1975). Of the 48 recorded species of Cayman Islands land molluscs, 30 are endemic, and 17 of these are related to Jamaican species, 10 with Cuban, 1 with the Isles of Pines, and 2 with Central America (W.J. Clench 1964); Pilsbry's (1930) inference of a former land connection with Jamaica cannot now be sustained (Thompson 1974). Both the fauna and the flora of Little Cayman have presumably been derived from the Greater Antilles by chance dispersal, and it is to these islands that we should turn in looking for analogues of Cayman ecosystems, as well as to islands of similar geology, topography and climate such as the Swan Islands, Anegada and Barbuda.

Extinct species

Little Cayman has the distinction of being one of the least settled and hence least disturbed of all the islands of the Caribbean. It owes this distinction to its rugged topography on dissected limestone; its low and erratic rainfall, its brackish watertable, and hence erratic water supply; its tangled and often impenetrable vegetation, dominated by scrub woodland; and its astonishing level of infestation by the mosquito *Aedes taeniorhynchus*. Nevertheless, in spite of its handfull of inhabitants, and partly because of its proximity to Cayman Brac, the island has not been wholly unaffected by change in post-Columbian times. This Expedition had for its main purpose the documentation of the present fauna and flora of the island: there are, however, important components of the biota already now extinct.

Reptiles

Both ground and arboreal reptiles form a conspicuous element in the fauna of Little Cayman, with two gekkoes (one not seen in 1975), four species of iguanid, one anguid, and two snakes (one also not seen in 1975). The crocodile is probably now extinct, however, and marine turtles probably hardly ever now breed on Little Cayman shores.

In 1642 William Jackson mentioned "ye multitude of Alligators" in the Caymans as a whole (Jackson 1924, 21), and early Spanish charts named the islands 'Lagartos' (alligators), a name, however, which Grant (1940, 5) thinks referred to *Cyclura* rather than to crocodiles. The first scientific report of crocodiles is that by C.J. Maynard in Garman's (1888, 108) paper on the former's collections. Maynard states that "Two species of crocodile have been taken on this island and one on Cayman Brac. I saw but a portion of one specimen. The natives assured me that the species were similar to those found in Cuba". Chapman Grant collected on Little Cayman in April 1938, as did C. Bernard Lewis in May-June the same year. They evidently did not see the crocodile, but Grant (1940, 14) records that "On October 27, 1939, Captain James Banks of Little Cayman sent the writer the head and feet of a crocodile which he took on that island. The head measures 310 mm in length. The dentition agrees with the Jamaican specimens of *acutus* in the author's collection. The crocodile was about seven feet long and was one of two which Captain Banks came upon near Charles Bay — about half-way along the south coast of Little Cayman". There is no subsequent record of living crocodiles on the island, and it is highly unlikely that the species still exists there. There is no means now of knowing with certainty whether there was a large and resident local population, or whether occasional individuals drifted to the island from Jamaica or Cuba; it is possible that recolonisation might occur from these islands.

Marine turtles have been equally extirpated locally. Turtling apparently began on a considerable scale in the Caymans in the second half of the seventeenth century (Dampier 1729, 30), although Columbus in 1503 had found the islands to be "full of tortoises, as was all the sea about". Hans Sloane passed through the Lesser Caymans in March

1688, when Cayman Brac already had "some Huts for the Turtlers", though by that time the turtles there "were but few" (Sloane 1725, 342). He described 40 sloops from Port Royal, Jamaica, as constituting the turtling fleet, with a four-man sloop bringing in 30-50 turtles which in good conditions might be collected in a single day (Sloane 1707, xvii, lxxxviii). It was believed that the turtles migrated from the Gulf of Honduras and the Nicaraguan Banks to breed in the Caymans and along the south coast of Cuba during May-September. Long (1774, 309-313) gives a detailed account of the natural history of the turtle and of the Cayman turtle trade. By the early nineteenth century, however, Caymanian turtlers were obtaining all their turtles on the Mosquito Keys and the coast of Nicaragua (Young 1842, 17-18), as well as off Cuba.

All of this information relates to the Green Turtle *Chelonia mydas*. Undoubtedly its main nesting grounds were in West Bay, Grand Cayman, with subsidiary populations on the more restricted beaches elsewhere. On Little Cayman the main nesting areas were probably at Sandy Point and on the narrow but long beaches of the north and south coasts. Lewis (1940, 62-64) also referred to the Loggerhead *Caretta caretta* as "still common" and breeding on all three islands in June; the Hawksbill *Eretmochelys imbricata* as "fairly common" though rarely laying; and the Leatherback *Dermochelys coriacea* as "rarely seen" but occasionally breeding. Breeding of any species of turtle in the Cayman Islands is probably now a rather unusual event, though perhaps least so on Little Cayman. As populations, however, the Cayman turtles now no longer exist.

We have no information on the present status of the gecko *Aristelliger praesignis* and the snake *Tropidophis caymanensis parkeri*, previously recorded but not found by Hounscome in 1975.

Mammals

No native mammals have been recorded from Little Cayman. In 1965, however, Patton (1966) discovered remains of the insectivore *Nesophontes* and the rodent *Geocapromys* on Cayman Brac. Both genera are representatives of a distinctive native Greater Antillean mammal fauna. *Nesophontes* is represented by fossil remains on Cuba, Hispaniola and Puerto Rico. *Geocapromys*, the short-tailed hutia, is represented by fossil and living species in Cuba, Jamaica, the Bahamas, and Little Swan Island (where it has recently been reported to have become extinct: Clough 1976). In addition, Darlington (1965, 391) records a fossil long-tailed hutia *Capromys* from the Cayman Islands; this genus is represented by living species in Cuba and the Isle of Pines. Though not so far recorded on Little Cayman, it would be surprising if the study of cave deposits did not lead to the discovery of fossil vertebrates on the island. So far nothing is known of their age on Cayman Brac, or of the reasons for their extermination, but at least on Little Swan *Geocapromys* survived until ca 1950.

Species at risk

Although conservation of species is best considered in terms of conservation of habitats, it is nevertheless useful to consider which taxa might be at risk if development of Little Cayman takes place.

Molluscs

Hounscome and Askew (this volume) have fully documented the rarity of the Little Cayman pulmonate *Cerion nanus*. It is clear that this species would immediately become extinct if its habitat of *Evolvulus* scrub were to be cleared, and since the main area of this scrub lies on the trans-island track from Blossom Village, close to possible development sites, this seems highly likely to occur. It is more difficult to estimate the seriousness of such an extinction, especially in so widespread and variable a genus as *Cerion*, which, moreover, S.J. Gould and his collaborators are currently subjecting to major revision.

Reptiles

The large iguanid of the genus *Cyclura* is of particular interest in the Cayman Islands. This genus is widespread in the Greater Antilles: in Cuba, the Isle of Pines, Hispaniola, Jamaica, Puerto Rico, Navassa, the Bahamas, Anegada, and the Turks and Caicos Islands, though over some of this range it is represented only by fossil or recently extinct species (Schwartz and Thomas 1965). Ecologically, it may be compared with the Central American genera *Ctenosaura* (which reaches out into the Caribbean at Half Moon Cay, Lighthouse Reef, Belize) and *Iguana* (found on Swan Island), and to a lesser degree with *Amblyrhynchus* and *Conolophus* in the Galápagos Islands. The species on Little Cayman (*Cyclura nubila caymanensis* Barbour and Noble) is also native on Cayman Brac, and has been introduced to Grand Cayman, where there is another native subspecies, *C. n. lewisi* Grant.

Grant (1940, 29-37) described the Cayman Islands *Cyclura* in detail, including ecological notes by C.B. Lewis. The lizards are herbivorous, and on Little Cayman feed on *Ipomoea pes-caprae*, *Ernodea littoralis* and *Cordia sebestena*. Lewis noted that they were only seen within 100 yards of the shore. Carey (1966) has studied *C. n. caymanensis* on Cayman Brac, where in 1965 it was confined to a small area on the southwest side of the island. Lewis (1944, 95) considered that the colonies of *Cyclura* on both islands "are reproducing, generally flourishing and are in no danger of extinction". However, he also stated (in Grant 1940, 34) that "the populations are rapidly being reduced by dogs, which these lizards seem unable to escape, although fighting well and occasionally injuring their attacker. There is a large colony on the south shore of Little Cayman at mid-island, which is at present sufficiently isolated to escape persecution by dogs and man".

There is no doubt that *Cyclura* is particularly vulnerable to predation by introduced mammals. In Jamaica *Cyclura collei* is now

extinct, despite efforts to preserve it, as a result of the introduction of mongoose in 1872 (Lewis 1944). *C. cornuta onchiopsis* has also become extinct on Navassa, and *C. mattea* and *C. portoricensis* are known only from fossil material on St Thomas, Virgin Islands, and in Puerto Rico, respectively. The rapidity with which extinction can take place has been documented for Pine Cay, Turks and Caicos Islands, by Iverson (1978), where in the early 1970s there was a population of 5500 individuals of *C. carinata*. A hotel was built on the island in 1973, and domestic cats and dogs introduced. These preyed on the lizards, which had become extinct by 1978. Iverson comments (1978, 63) that these rock iguanas are "among the most rapidly declining of the world's reptile species".

C. nubila caymanensis is only commonly seen on Little Cayman in the vicinity of South Hole Sound. The former isolation of this area has disappeared with the construction of the circum-island road and the airfield. It would seem almost inevitable that dogs and cats would be introduced in consequence of any industrial or tourist development, and even if they were controlled the areas in which the lizards are found would be at great risk from direct habitat modification. There is an urgent need for a full investigation of this species on Little Cayman, since at present our information is inadequate for the formulation of a conservation policy for it. Indeed, cyclurid lizards are only well known in the similar habitat of Anegada, where *C. pinguis* has been studied by Carey (1975). On scientific grounds, too, it would be of great interest to compare *Cyclura* with the mainland iguanid *Ctenosaura similis*, recently studied in Belize and Nicaragua (Henderson 1973, Fitch and Henderson 1978).

Birds

As Diamond (this volume) has shown, the land birds are generally numerous and not immediately at risk, except as a result of massive habitat change; this appears unlikely to occur except on a very local scale. The seabirds are, however, more vulnerable. This is particularly true of the colony of Red-footed Booby on the northern margins of the Blossom Village salt-pond. While this is now known to consist of the pantropical species *Sula sula*, rather than the originally described endemic *S. coryi*, it is nevertheless of considerable importance in Caribbean terms, and may indeed be the largest colony of this species in the area. Diamond estimates that it includes at least 7100 birds. The only comparable colonies appear to be those on Half Moon Cay, Lighthouse Reef, Belize, where Verner (1961) estimated a population of 3500, excluding nestlings, and on Little Swan Island. There is no estimate of the size of the latter population, though it has been described as large by Lowe (1909), Fisher and Wetmore (1931), and Stewart (1960); there is no subsequent information on its status.

The number of Magnificent Frigatebirds *Fregata magnificens* in the same colony on Little Cayman is much smaller, and there are much larger colonies on Barbuda (2500 pairs: Diamond 1973), the north coast of Yucatan (2500 nests, quoted by Diamond 1973), and on Little Swan Island, where, however, there is no recent information on the size of

the colony.

Habitats at risk

As Diamond (this volume) has succinctly stated: "It is in the almost completely undisturbed nature of the island as a whole that its chief biological interest lies". It follows that the arguments for conservation lie less in concern for particular individual species than for undisturbed habitats. The interest of Little Cayman lies in its rugged and difficult terrain; its undisturbed scrub, scrub woodland, and woodland; its reptile fauna dominated by the ground iguana *Cyclura* and abundant arboreal lizards; its enormous decapod crustacean populations, especially of *Cardisoma guanhumi*; its 600 species of insects; its land-birds; and its seabirds, all co-existing under conditions little affected by man. The main habitats of conservation interest are as follows (Figure 34).

Interior woodland

The area of tall Dry Evergreen Forest in the interior of the island is, ecologically, one of the most remarkable habitats of Little Cayman. On most other smaller Caribbean islands (e.g. Barbuda) such woodland has long since disappeared, but on Little Cayman it remains extremely isolated and virtually undisturbed. Its preservation is thus of far more than local significance: it is of Caribbean-wide importance. This is so in spite of the fact that it is not obviously associated with spectacular, rare or threatened species, though Hounscome (this volume) collected some 16 species of terrestrial animals (other than insects) only in this habitat.

Mangrove woodland

Two areas of mangrove woodland require conservation. One is that on the north shore of the Blossom Village salt-pond, used by the nesting boobies. This is not only susceptible to clearance, but also to disturbance by repeated visiting, and by overflying from the adjacent airfield. Diamond has shown that the booby colony is one of the largest in the Caribbean, and its conservation is thus of regional importance. The second area is the tall mangrove woodland around Tarpon Lake. This is of local importance as a representative of this type of habitat on Little Cayman, though of course widespread in other parts of the Caribbean, including Grand Cayman; it also has some amenity potential. Inland areas of dwarf *Rhizophora* are also ecologically interesting, and less widespread in the Caribbean than other types of mangrove habitat.

Evolvulus heath

The importance of this habitat has already been discussed in the context of the preservation of the land snail *Cerion nanus*.

Sesuvium marsh

The inland monospecific herbaceous marsh dominated by *Sesuvium portulacastrum* at the east end of Little Cayman represents a very unusual habitat. It is important for its insect populations, especially of dragonflies, and possibly also for the tree duck *Dendrocygna arborea*. It is difficult to imagine so remote an area being directly disturbed, however.

Coastal flats

These areas have already been greatly disturbed, especially by the general planting of coconuts at the end of the nineteenth century, by other cultivation and clearing, and by settlement. This has had the result of replacing what was probably a rather uniform strand woodland by new types of woodland, scrub, and open herbaceous habitats. Askew (this volume) has noted the diversity of insects in these coastal areas. Now that access by road is possible along almost the entire coast, it has become more important to preserve the surviving remnants of native coastal woodland, and to attempt to control the activities of introduced animals. Rats are now ubiquitous in the coastal areas, but cats and dogs appear still to be confined to the settlements. The prevention of erosion during storms is also critically dependent on the preservation, wherever possible, of beach-crest scrub and scrub woodland.

Marine habitats

During the 1975 Expedition marine studies were concentrated on the habitats of South Hole Sound, in view of its tourist potential and also susceptibility to change in the event of expanding settlement at Blossom Village, and on the littoral fauna and flora round the whole island (Potts, this volume). It is likely that reef-flat and reef faunas and floras are closely comparable with those more intensively investigated on Grand Cayman (Rigby and Roberts 1976, Raymont, Lockwood, Hull and Swain 1976a, 1976b). There is no reason to suppose that Cayman marine habitats differ in any fundamental way from those characteristic of Caribbean coral reefs in general (Stoddart 1977), but it is certainly true that, especially in the Lesser Caymans, disturbance by man has been minimal, in contrast to many other Caribbean localities. As a result, reef fish faunas have not been disrupted by spearfishing and are thus of considerable scientific interest (Potts, in preparation).

Two main marine areas have been recommended by Potts (1975) as marine reserves (Figure 34). They are:

- (a) The eastern, windward end of the island, with well-developed coral reefs, remote from any settlement.
- (b) The area on the northeast coast from Salt Rocks to Jackson's Point.

This second area includes the interesting intertidal and supratidal exposure of Ironshore at Salt Rocks, and the so-called 'Cayman Wall', a

steep reef-edge drop-off in Bloody Bay, which plunges vertically from 10 to 200 m. This latter is already well-known to divers.

Conflict between conservation requirements and development proposals would appear, however, to be inevitable in the marine sphere. Proposals now being implemented call for tanker trans-shipment facilities, with shore installations, at Salt Rocks, and for docking facilities along the Bloody Bay drop-off. There remains the possibility of establishing a marine reserve at the eastern end, and also of emphasising the need for further studies in the reef areas likely to be directly affected by development.

Conclusion

As so often, the scientific interest and importance of an island only becomes recognized when large-scale development is planned. Although the Oxford University Expedition of 1938 supplied the groundwork of our knowledge of the fauna and flora of Little Cayman, it was not until 1975 that an attempt was made to distinguish marine and terrestrial habitats which might be at risk in the event of development. We are now in a position to appreciate with greater precision than before the impact of industrialisation on such an island, and we have been able to define areas of scientific importance which should be conserved during any such development. At the same time, we should emphasise that this report is based on only one month's investigation, and note that not only is there a great deal of further work to be done but that such studies should form an integral part of any scheme for the future of the island. The natural habitats of Little Cayman are of sufficient importance to be considered in a Caribbean rather than simply a Caymanian context, since few similar undisturbed environments still survive elsewhere, and it would be short-sighted in the extreme to damage a heritage and resource of this character for immediate economic advantage without the fullest consideration of the irreversible consequences of development and of the alternative strategies which may still be open for the future.

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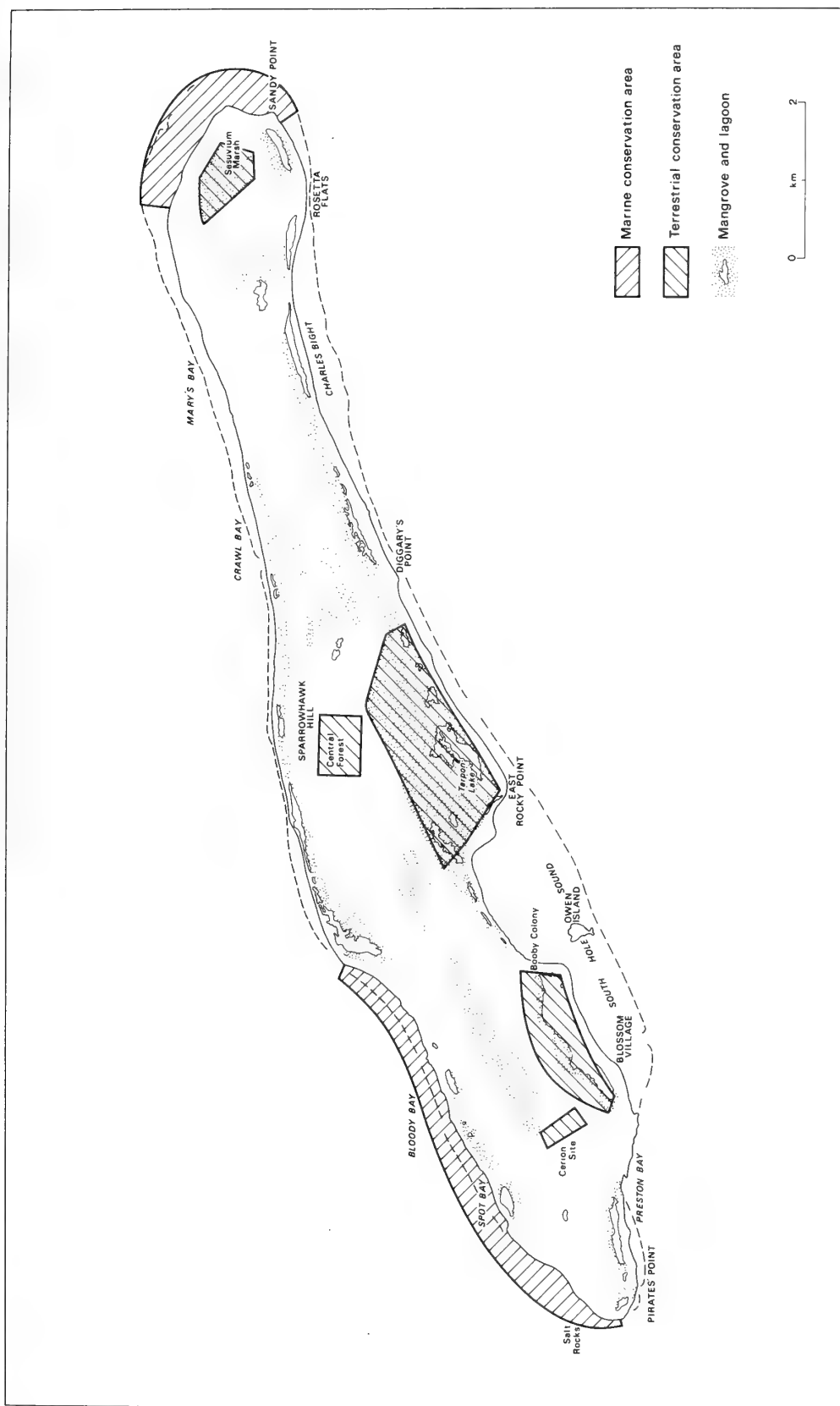
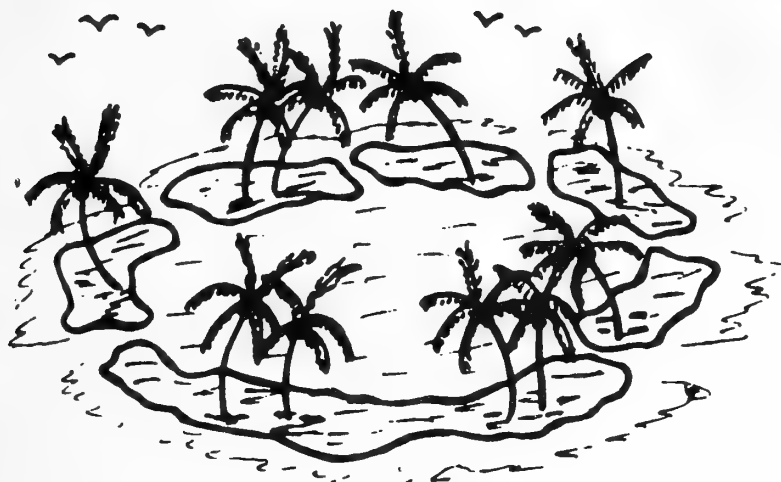


Figure 34. Recommended marine and terrestrial conservation areas, Little Cayman

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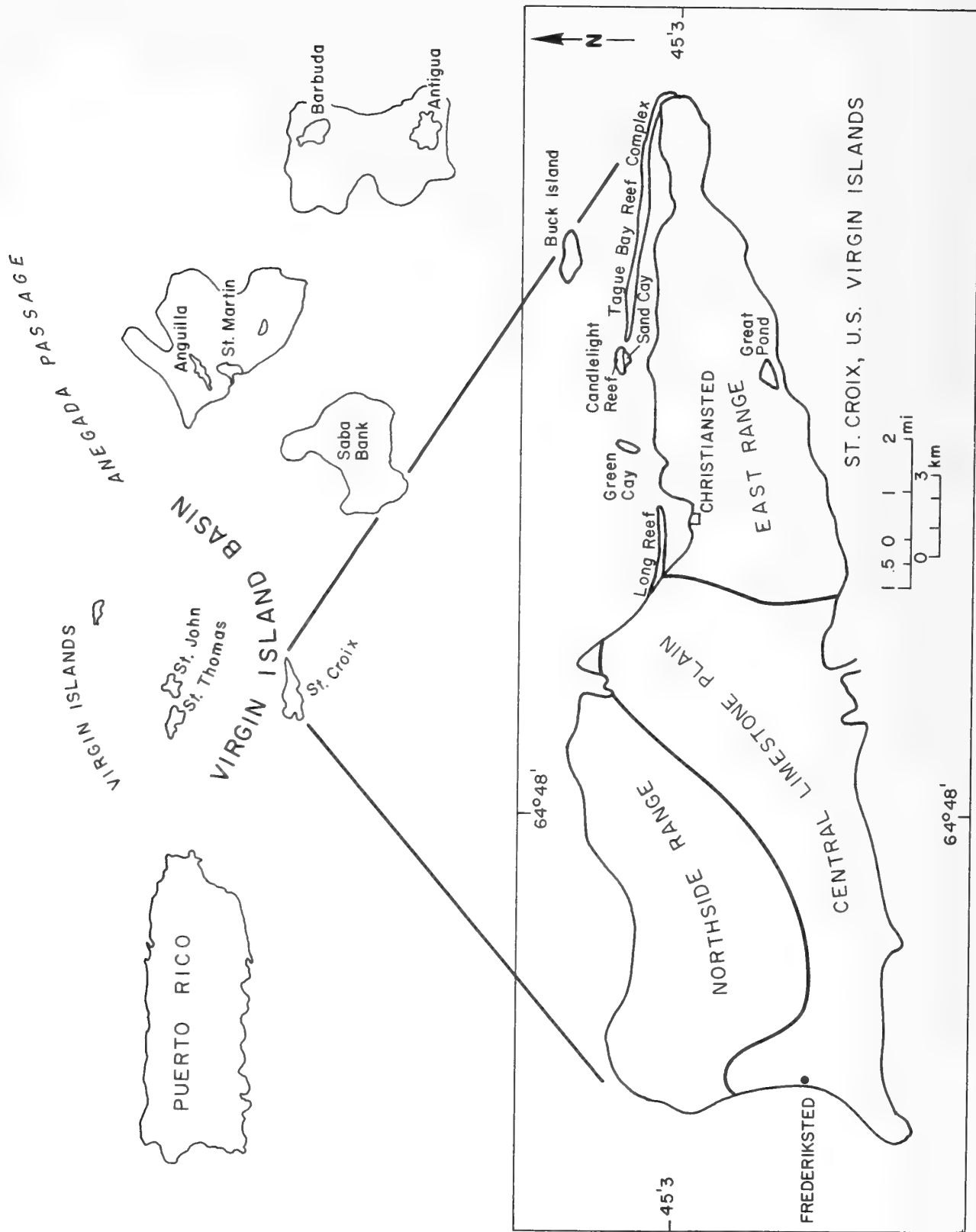


Fig. 1 Index map showing location of St. Croix, Candlelight Reef, and other geographic features.

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**ORIGIN AND EVOLUTION OF THE CANDLELIGHT
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by Lee C. Gerhard

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ERRATUM

The following caption should be inserted for figure 7:

Fig. 7. Temperature in and near a small clump of vegetation on Cayo Ahogado. Dots: 5 cm deep in soil under clump. Circles: 1 cm deep in soil under clump. Triangles: Soil surface under clump. Squares: Surface of vegetation. X's: Air at center of clump. Broken line indicates intervals of more than one hour between measurements.

ORIGIN AND EVOLUTION OF THE CANDLELIGHT REEF-SAND CAY SYSTEM, ST. CROIX

by Lee C. Gerhard¹

INTRODUCTION

The island of St. Croix, largest and most southerly of the U.S. Virgin Islands (Fig. 1) is bordered on its northeastern margin by a well-developed *Acropora palmata* reef that extends from the eastern tip of the island over five miles (8 km) westward. The western terminus of the reef is a large patch reef (Candlelight reef), slightly separated from the main reef by one of only three boat channels crossing the bay-barrier reef.

Prevailing wave trains are from the east and northeast; the reef exhibits higher energy communities in the eastern portions, including coralline algal caps. Poorly developed, very small bays and lagoons are present behind the reef (see also Gerhard and Stoltzman, 1974). The western trailing edge gradually diverges northward from the coastline and bars deeper and broader lagoons, the most westerly of which is called Coakley bay. Candlelight reef is at the western extremity of Coakley bay.

Candlelight reef has a broad reef flat which is in part covered by a sand pile, locally called Sand Cay, which changes size and shape periodically (Fig. 2).

Bathymetric profiling (Fig. 3) through Coakley Bay indicated an anomolous shallow ridge, a ledge of rock extends from the southeast corner of Coakley Bay shoreline towards Sand Cay, and Sand Cay was found to contain detrital cobbles of mainland rocks (Caledonia Formation, Cretaceous), although separated from mainland by topographic depression.

¹North Dakota Geological Survey University of North Dakota Grand Forks, North Dakota 58202. Manuscript received March 1979 --Eds.

The purpose of this study was to try to determine the control for the location of the major northeastern St. Croix bay-barrier reef western termination and to study the atypical nature of Coakley bay and Candlelight reef.

METHODS

Studying the origin and evolution of the reef, cay, strandline, and lagoon of this complex required several sampling methods not commonly employed in terrestrial field studies. Although normal SCUBA and free diving techniques were used throughout the study, two coring methods were instrumental to the study.

Three holes were drilled through Candlelight reef (Fig. 3) by means of a portable gasoline-powered drill. When major sand bodies were encountered, as on the east end of Sand Cay, concrete reinforcing bar was driven into the sediment; ease of driving (hammer blows per foot) changed as a function of depth and material penetrated; however, an abrupt change marked the contact between sand and underlying detrital muds. In the western hole, a soil sampling tube was lowered through the drilled hole and driven completely through the muds. Eight feet of mud was recovered; a chip of underlying limestone substrate was also recovered from the collapsed core barrel. Drilling was done from a drilling platform constructed of tubular aluminum and anchored to the reef. This permitted use of block and tackle for retrieval of drill tubing and reentry of holes.

Cores taken in the lagoon were taken by SCUBA diver teams operating a 100 pound sliding hammer over aluminum irrigation pipe or plastic ewing piston corer linear. A locking handle on the core barrels acted as the anvil for the sliding hammer. This method penetrated sands and gravels without difficulty. Where the core barrel penetrated mud, the mud effectively sealed the core barrel from sample loss. In at least one case (S-5) where the core barrel could not penetrate coarse sediment, a concrete reinforcing bar was driven into dense substrate, recovering mud adhering to the pits and ridges ornamenting the bar.

Mud mineralogy was analyzed by X-ray diffraction. Two radio-carbon dates were run on *Montastrea annularis* from the western drilled hole.

GENERAL SETTING

Candlelight reef forms the seaward margin of a small, complex lagoon named Coakley Bay (Fig. 4). The reef proper is covered with *Acropora palmata*, with smaller amounts of *Porites*, *Montastrea*, and *Diploria* present. The reef flat is partly algal turf with large numbers of the grazing urchins, *Diadema antillarum* occupying the transition between the reef fauna and the algal turf. *Thalassia testudinum*, turtle grass, is common on the reef flat and on the lagoon

side of the reef. *Echinometra* (echinoid) is also abundant in crevices of the reef flat.

During much of the year wave interference produces a westward elongation of the sand bar on top of the reef (Sand Cay). Winter storm waves may change the shape of the cay rapidly, although the position of the island may now be stabilized by a shipwreck. The highest part of the cay, about 0.5 meter above MSL, supports sparse vegetation. Shell middens from both modern and former human populations also are wave-worked into the cay.

The lagoon or bay floor is covered with *Thalassia* except near the strandline where open, rippled sand is present, and back of the cemented sand "beachrock" ridge (Fig. 3) where pavements of coral and mollusc rubble occur. The strandline in the eastern part of the bay is a series of beachrock layers. Bedrock (Caledonia Formation) is exposed on points defining the eastern and western limits of the bay.

The ridge of cemented sand in the southeast, the lobe in the -5 meter contour at core location S-2, and the submarine ridge connecting Candelight reef to the mainland point at the western end of the bay are the most important features of the lagoon (Fig. 3). The "beachrock" ridge appears to deflect the normal longshore current seaward, and water has always been observed to be more turbid along that ridge than elsewhere in the lagoon; the biota of the ridge is largely alcyonarians and deeper water corals, such as *Eusmilia*. This appears to substantiate the continuing high turbidity which produces lower light levels. The corals are poorly calcified as compared to more clear water forms, as well.

Strandline features are a steep sandy beach and beachrock in the eastern part. The sand beach is a bar separating a saltpond from the lagoon. Two passes cut through the bar, a small, now blocked, one at the west end, and a drainage at the east end which is the major channel between the pond and the lagoon. During periods of dry weather, the pond is dry, with blue-green algal crust chips and gypsum crystals on the surface; during high rainfall the pond will hold water to about 0.5 meters deep; excess water exits through the eastern channel. Beachrock starts downcurrent from the point of entrance of the pond drainage into the lagoon.

It appears that the beachrock cementation along the present strandline is at least in part due to the outflow from the pond. Perhaps excess salinity, or driving of hypersaline waters by freshwater runoff may force precipitation of cement (Hanor, 1978; Hanor and Moore, 1974).

The sediment cover of the present lagoon floor does not contain appreciable clastics; no detrital grains larger than sand size are found more than a few meters from exposed Caledonia Formation. Therefore, detrital cobbles on Sand Cay are not now being transported from a bedrock source to the cay.

SEDIMENT FACIES

Lagoon cores contain sediments of several different depositional environments (Appendix A). In all cases, the uppermost beds or zones are low in detrital grains and contain large amounts of skeletal sand, including many *Halimeda* plates, both whole and broken. This reflects the prevailing modern depositional setting of grassbeds with associated codiacean algae and molluscs. Ten to twenty centimeters below the top of each core the amount of detrital grains abruptly increases. A shoreline to lagoon environmental transition can be seen between core S-1, S-2, and S-3 in this zone (Fig. 5). Discoidal beach pebbles in core S-1 are in the same stratigraphic position as a zone of broken mollusc and coarse detrital grain in core S-2, which in turn corresponds with detrital sand mixed with *Halimeda* and mollusc in S-3. Movement of the beach zone upwards from core S-2 to S-1 is indicated by the coarse detrital cobble with *Siderastrea* in the base of core S-2, overlying clastic mud, whereas in core S-1 that position is occupied by clastic mud with some marine mollusc fragments and some *Halimeda*.

Core S-4 also is high in detrital grains in the depth below the existing grassbed. These grains are coarse, pebbles and gravels, but do not exhibit the discoidal shape of pebbles in core S-1.

Two cores were taken in the next bay to the east (S-6, S-7) for comparison. Core S-7, near the shoreline, exhibited no unusual sediments, but core S-6, in a backreef location, cut a cemented layer just above the yellow mud bottom (Fig. 6).

All cores except S-4 penetrated the carbonate sediments and recovered a dense blue or green mud substrate, as did two of three holes drilled on the reef.

Three cores were taken in the vicinity of Green Cay to the west to test for the presence of the dense mud in that area; two recovered mud. One of these was seaward of Green Cay, but behind a lineation apparently marking an outward limit of mud and clastics (Fig. 4).

Three holes drilled around Sand Cay encountered a cap of coral rubble, mixed coral rubble and sand (approximately 3 meters thick in each case) and then thick skeletal sand. Two holes, west and east of the cay, encountered dense mud below the sand; the third in front of the island encountered limestone. In the western core, the mud was cored through to limestone (Fig. 7). This limestone appears to be of Pleistocene age and is an indurated coral-mollusc-*Halimeda* bank. The same material was encountered in core holes further east along the reef, without any mud being present. Thus, at the reef crest, no mud is present and the reef appears to be constructed on an older limestone "lip".

Carbon 14 data on *Montastrea annularis* from the base of the rubble zone in drill hole 1 (west side of Sand Cay) gave results of 1495 ± 65 years and 1750 ± 200 years, which fits well with the sea level curve

used by Adey (Adey and Burke, 1976).

MUD SUBSTRATE

Almost all cores in this study, plus two more near Green Cay, recovered blue-green or blue-gray muds, the exceptions being cores drilled on top of the reef, where mud was not present over older limestone, and those that had mechanical penetration problems. Additional probes (S-5) established presence of mud in areas where it was not cored.

X-ray diffraction analysis of these muds indicates quartz to be the major constituent with calcite, aragonite, plagioclase, and halite also present in significant amounts. These analyses are similar to muds sampled at shallow depth in Great Pond, on the opposite side of the island, which is a pond with a single narrow channel for tidal communication. The quartz is largely the result of weathering of the fine-grained turbidites of the Caledonia Formation, and some quartz, plagioclase, and perhaps, where present, hornblende, are from the Southgate diorite which crops out in a belt across the island from Great Pond to Green Cay. The mud has a sloping surface in the Coakley bay area (Fig. 8), rising southward and apparently joining the existing salt pond surface (Fig. 9).

ORIGIN AND EVOLUTION OF CANDLELIGHT REEF AND COAKLEY BAY

Drilling has determined that a Pleistocene or older limestone underlies the length of the northeastern St. Croix bay-barrier reef, at least from Candlelight reef to Tague Bay, and probably through Boiler Bay to the east. Presence of a raised lip on this platform of limestone is indicated by the closely spaced drilling around Candlelight reef, where the reef margin limestone substrate is shoaler than behind the reef. In addition, under the reef, no mud is present between carbonate sands and the limestone, but it is present everywhere else in the lagoon behind Candlelight reef.

Adey and Burke (1976) have related sea level rise with time for St. Croix. Based on their graphs and the radiometric dates from Candlelight reef, a scenario of events from approximately 5500 yr BP to present can be constructed (Fig. 10).

The mineralogic identity of cored muds to those in the present salt pond, the transgressive character of the sediments overlying the muds, and the gradual rise of that surface from reef to shoreline all suggest that all the muds were deposited in restricted circulation saline environments, probably similar to the present barred pond.

Initial transgression over the lip of the *Porites* limestone would have created a bar on top of the limestone (an extension of the former beach) with a restricted pond or lagoon behind. Muds deposited in this pond in part cover the earlier limestone.

The original trend was parallel to the existing reef trend. As transgression progressed, the sand bar was moved landward and reef colonization progressed on the original declivity over the limestone lip. Longshore current from the east was developed.

At Coakley bay, however, a combination of current deflection by rock ridges and fluvial interferences from the Southgate drainage at Green Cay deflected the longshore current northward, and a spit was developed north from western Coakley Bay, along which clastics were transported northward.

The bar by this time was moved shoreward, but was anchored at the site of Candlelight reef by the growing spit. The spit is now the submarine ridge between Candlelight reef and the shoreline.

The next step, at about 3000 yr BP and -2 meters sea stand a pond was enclosed by the remnant bar and spit (Fig. 10D). Drainage from the pond helped form beachrock, which still exists as the submerged line of cemented material in the eastern part of Coakley Bay. A later pond drainage channel may be on the site of the -5 meter bathymetric contour nose at S-2 (Fig. 3). There is no doubt that a well-developed beach existed at S-1 where discoidal beach pebbles are present, transported northward by longshore currents.

Clastics were carried out to the site of Candlelight reef by longshore drift along both spit and bar, creating a pile of debris at their conjunction. As *Acropora palmata* was established, reef colonization became rapid.

The current transgressive episode slowed and the spit-bar combination migrated shoreward to its present position, barring the present salt pond.

SUMMARY

Candlelight reef is the buttressing western terminus of the northeastern St. Croix reef system because of a combination of paleo-topography and longshore drift which created a stable pile of detrital material at the position of Candlelight reef. Reef colonization proceeded eastward along the former slope break on the limestone terrace; turbid gyres along the eastern margin of the former Southgate drainage prevented further westward colonization. It is quite possible that the old limestone bench has also been breached west of Candlelight reef, or else turns northwestward (which appears likely on aerial photographs).

The presence of detrital cobbles in Sand Cay and Candlelight reef is easily explained by this model, as well as the submerged ridge and submerged beachrock.

One of the interesting subsidiary results of this study is the demonstration that an unconformity between underlying fine-grained

quartzose rocks and overlying carbonates, with basal conglomerate, need represent only an eustatic sea level rise rather than any fundamental tectonic event. Dynamic environmental translocation of sediment bodies can appear to represent disconformities that do not really exist.

ACKNOWLEDGEMENTS

This study is a compilation of the work done by the writer, his students, and associates over several years. In particular, my 1975 summer Field Sedimentology class of the West Indies Laboratory, especially Kipp Carroll, Douglas George, and Rick Haack, did most of the coring. Dick Holt and Craig Shipp, then of the West Indies Laboratory, Jonathon Fuller, and Timothy Cross have all assisted in the completion of this study. Jon Reiten and David Brekke, of the University of North Dakota, made the X-ray diffraction analysis. Randolph Burke provided the C-14 analyses.

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APPENDIX A. CORE DESCRIPTIONS

S-1. On approximate line with submerged beachrock northwest of Mill Point.

- 0-17 cm *Halimeda*--clastic sand with *Thalassia* rhizomes. Contact with lower unit is fine-grained silty sand.
- 17-75 cm Gravel of discoidal pebbles of Caledonia Formation and large broken mollusc fragments in a fine sand matrix. Large clasts are aligned parallel to bedding. Bioclasts in part encrusted by *Petalocochnus*. *Cerithium* common. One ungaped *Pitar* at 65 cm.
- 75-82 cm Peat, unidentifiable origin, with minor carbonate grains and one large detrital clast.
- 82-91 cm Detrital-skeletal conglomerate; thin-shelled molluscs, *Halimeda*, like mangrove biota.
- 99-112 cm Blue-green mud with very few carbonate grains.
- 112-135 cm Blue-green mud.

S-2 Northeast of end of submerged beachrock.

- 0-26 cm *Halimeda* plates in fine-grained skeletal sand. A few mollusk fragments. Whole *Halimeda* plates in lower part of unit; *Thalassia* rhizomes in upper part. Transitioned contact with lower unit.
- 26-61 cm Medium-grained *Halimeda*-mollusc sand with detrital pebbles. *Mesophyllum* and gorgonian spicules are present, many *Cerithium*. Sharp contact with lower unit.
- 61-104 cm Massive bedded, clastic-mollusc gravel, clastics well-rounded, many small gastropods, a few large pelecypods.
- 104-126 cm Nearly the same as upper unit but average grain size of larger clasts is increased.
- 126-140 cm Clastic gravel in carbonate sand matrix. Lowest particle is fist-size detrital clast encrusted by *Siderastrea*. "Basal conglomerate."
- 140-153 cm (TD) Blue-green mud. Irregular contact like disconformity with overlying unit.

S-3 Northeast of S-2, outside (NE) of the submerged beachrock

- 0-9 cm Poorly sorted skeletal sand with few large mollusks. *Halimeda*, gastropods, pelecypods. Gradational contact with lower unit. *Thalassia* rhizomes present.
- 9-19 cm *Cerithium*, other large mollusks, *Halimeda*, in a fine-grained skeletal sand matrix. A few detrital medium to coarse sand grains. Contact with underlying unit is sharp.
- 19-56 cm *Cerithium* gravel with large numbers of unbroken *Halimeda* plates; minor matrix of fine-grained skeletal sand. Many smaller molluscs appear abraded. Gradational contact with underlying unit.
- 56-72 cm Skeletal sand grading downward from *Cerithium*-*Halimeda* gravel to mollusc sand. Some clastic sand grains.
- 72-95 cm Coarse pelecypod-clastic gravel with *Oculina*, *Cerithium*, *Nerites*, and crustose coralline algal coated *Porites*. Sand matrix. Contact with underlying unit irregular and sharp.
- 95-118 cm (TD) Yellow-green and blue-green mud. Contact with overlying unit has 2-3 cm relief. A minor amount of finely comminuted skeletal detritus.

Entire core exhibits very little bedding, may have been bioturbated, no preferential orientation of flat particles.

S-4 Taken on the submerged ridge between the western headland of Coakley Bay and Candlelight reef

- 0-8 cm Medium- to fine-grained sand with some relatively unbroken *Halimeda* plates: a few small mollusk shells. *Thalassia* rhizomes, few clastic grains. No bedding. Transitional contact with underlying unit.
- 8-24 cm Moderately coarse skeletal sand with fine-grained sand admixture grading downwards to base of unit which has large broken *Codakia* shells. *Halimeda* abundant. Some clastic sand, increases downwards. Abraded *Homotrema*. Transitional contact with underlying unit.
- 24-32 cm Coarse sand and gravel, whole *Cerithium*, other gastropods, large clastic grains, and broken *Halimeda* plates infiltrated with fine-grained sand. Clastics are rounded. Transitional contact with underlying unit.

- 32-69. Coarse clastic gravel, well rounded, as if beach pebbles; discoidal clasts. Abraded *Cerithium* shells, other large mollusc fragments. Contact with underlying unit is abrupt.
- 69-91 cm (TD) *Halimeda*-mollusc sand with well-rounded clastic granules and pebbles, but a much lesser amount than in overlying unit.

S-5 Probe, just northeast of S-4

Blue-green mud on probe tip at depth of 195 cm.

S-6b Taken in front of Coakley Bay condominiums a few meters lagoonward from reef

- 0-11 cm Coarse skeletal sand. May be washed.
- 11-32 cm Medium coarse skeletal sand, nearly 10% clastic sand grains.
- 32-68 cm *Halimeda*-mollusc-clastic gravel. *Cerithium* abundant. Well burrowed. *Homotrema* abundant.
- 68-83.5 cm Coarse mollusc valves, clastics, with less *Homotrema*. Cemented nodule of pelecypod fragments, oriented parallel with sediment-water surface, about 1 cm thick.
- 83.5-87 cm (TD) Yellow-green mud with few carbonate grains.

S-7 Taken just off beach in front of Coakley Bay condominiums

- 0-13 cm Fine-grained skeletal sand with foraminifera, *Halimeda* plates and *Thalassia* rhizomes. Molluscs common.
- 13-62 cm Overall coarser than overlying unit, poorly sorted with coral fragments, *Cerithium* and extremely abundant whole *Halimeda* plates. Clastics less than 10%. Many large mollusc valve fragments, including *Codakia*. *Oculina* and *Mesophyllum* both present. Gradational contact with underlying unit.
- 62-82 cm Grain size greatly increased because of very large mollusk fragments and sub-rounded to sub-angular detrital clasts. *Oculina* at top of unit and *Mesophyllum* is abundant. One large *Natica* is intact with root etchings. Many broken but fresh pelecypod shells. Contact with underlying unit is relatively sharp.
- 82-89 cm Fine-grained sand containing *Oculina*, *Mesophyllum*, and detrital sand. Abrupt contact with underlying unit.

89-99 cm (TD) Blue-green mud with few carbonate particles, surface with overlying unit 1-2 cm relief. Shell fragments appear to be thin-walled molluscs.

APPENDIX B. DRILLED HOLE LOGS

SC-1 West of Sand Cay

0-4 feet	Water
4-5 feet	Cap rock of coral rubble
5-10 feet	Sand and coral rubble
10-19 feet	Carbonate sand
19-25 feet	Blue-green mud
25-28 feet	Green mud
TD	<i>Porites</i> limestone (Pleistocene?)

SC-2 North of Sand Cay

0-4 feet	Water
4-5 feet	Cap rock of coral rubble
5-9 feet	Sand and coral rubble
9-25 feet	Carbonate sand
TD	Limestone

SC-3 East of Sand Cay

0-3 feet	Water
3-3.5 feet	Cap rock of coral rubble
3.5-9.5 feet	Sand and coral rubble
9.5-24 feet	Carbonate sand
24-24.4 feet TD	Blue-green mud

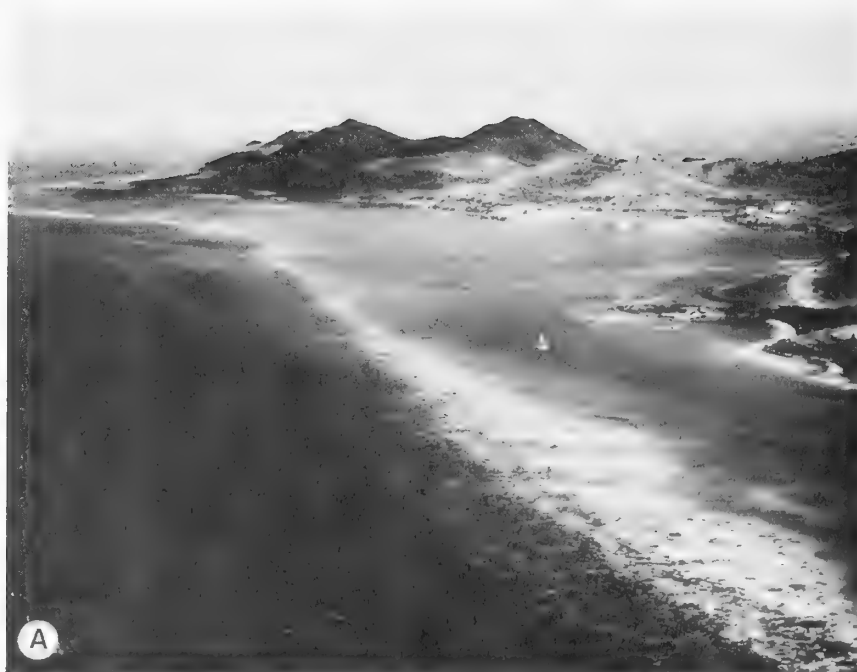
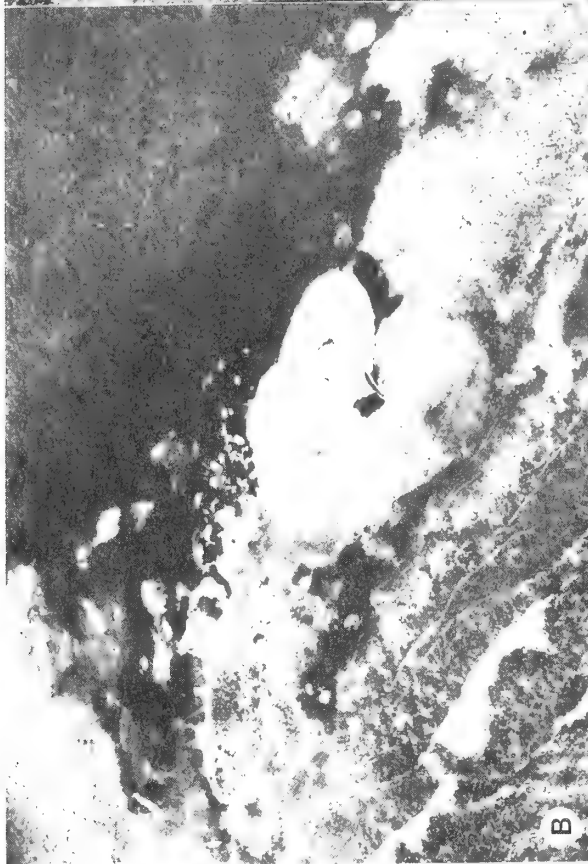


Fig. 2 Aerial photographs of Sand Cay and Tague Bay reef complex.
 A. Tague Bay reef complex, view looking east. *Acropora palmata* is major coral of reef crest. B. Sand Cay, August, 1973. C. Sand Cay, February, 1974. D. Sand Cay, March, 1977. E. Saltpond behind bar, Coakley Bay, St. Croix. B, C, and D looking south, E looking southeast.



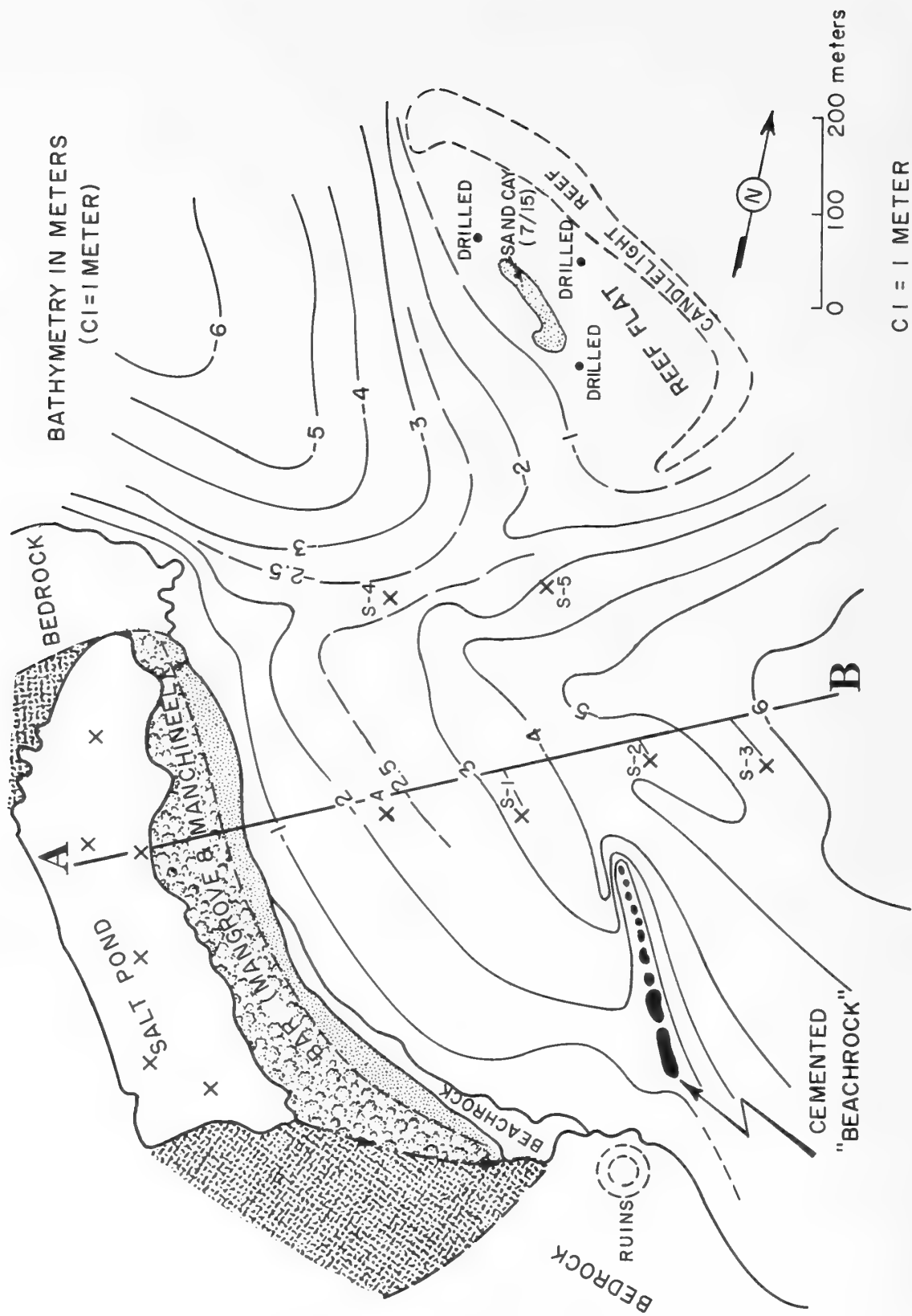


Fig. 3 Bathymetric map of Coakley Bay area, St. Croix, showing core locations (X) and line of section for figure 9.

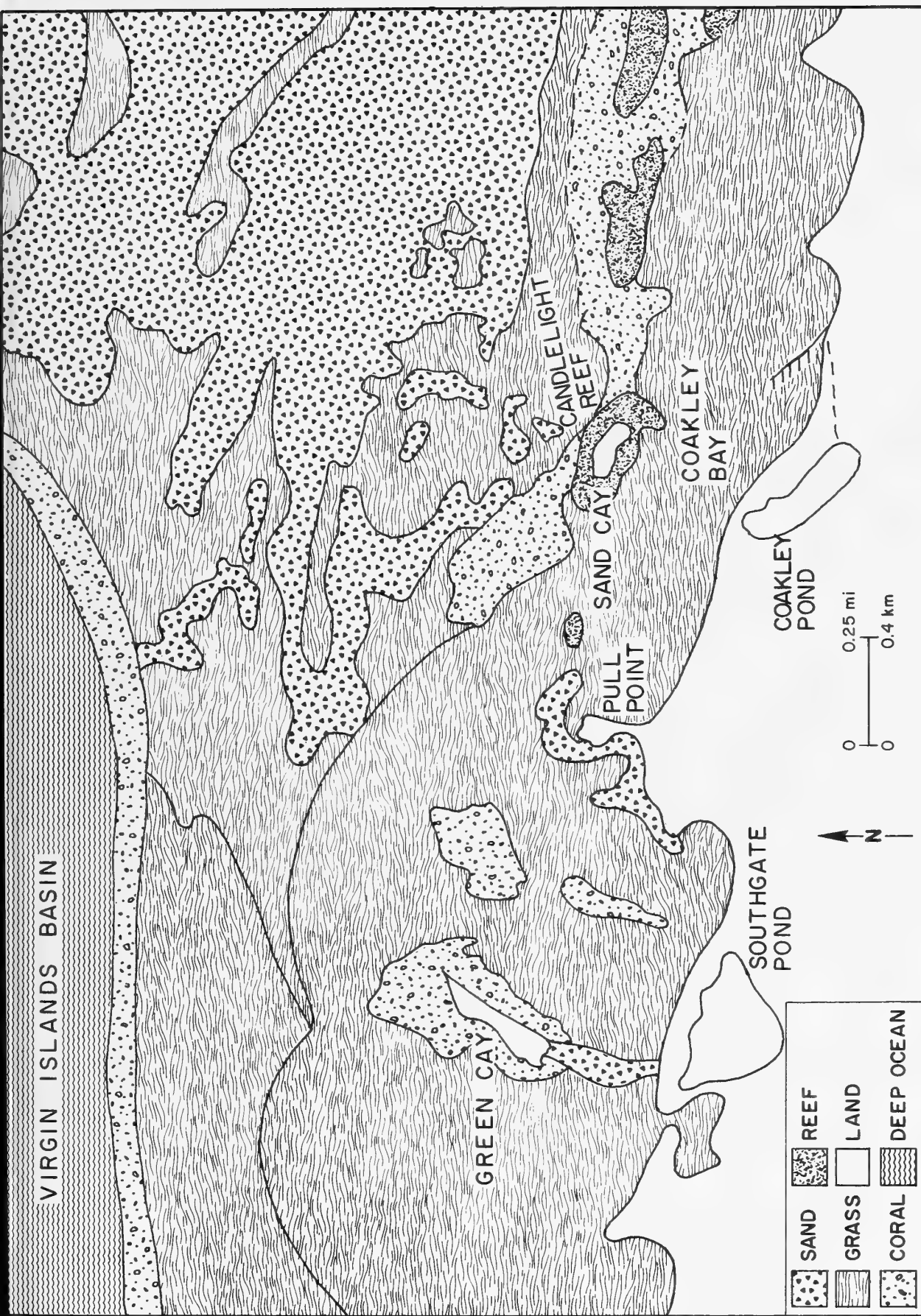


Fig. 4 Substrate types central north St. Croix shelf. Lineation north of Green Cay may indicate limit of muds or edge of Pleistocene limestone terrace; N-S lineation appears to be formed drainage channel.

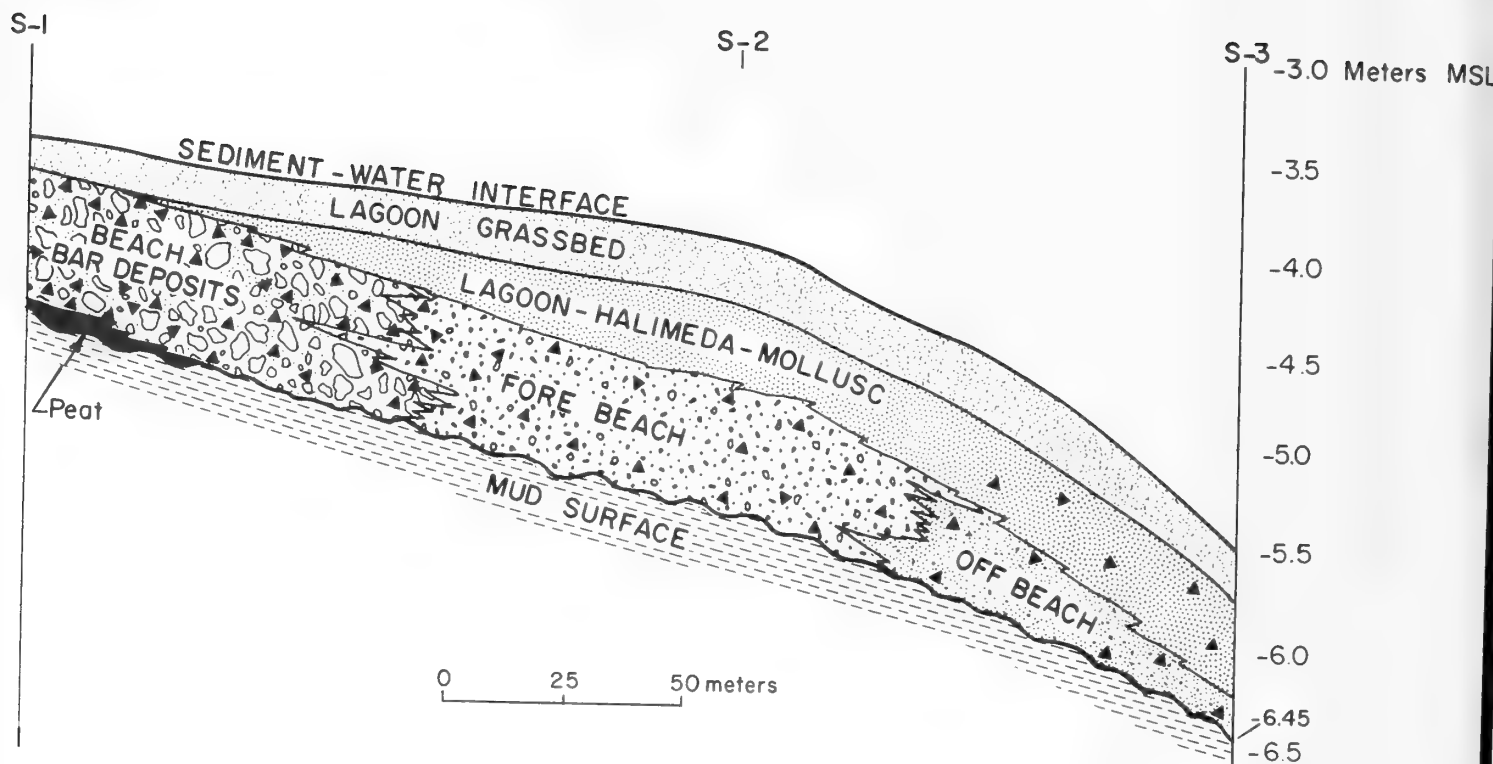


Fig. 5 Correlation of cores S-1, S-2, and S-3 with (a) interpreted environments of deposition. Dark triangles indicate relative abundance of detrital clasts. Photographs are from: (b) S-1 (59-71 cm); (c) S-2 (110-145 cm); (d) S-3 (71-85 cm); (e) S-3 (19-34 cm).

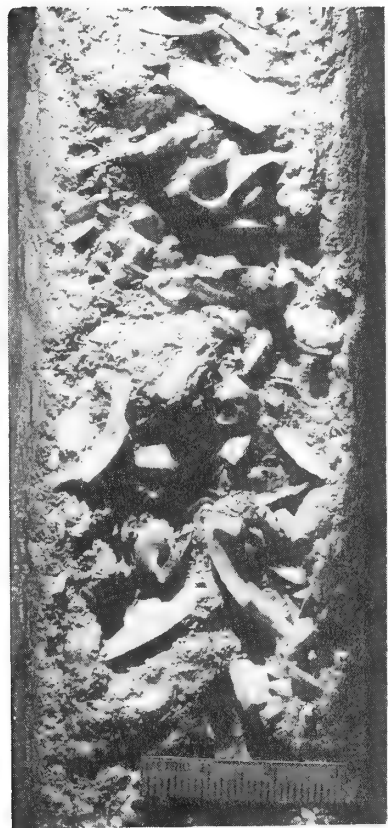
B.



C.



D.



E.



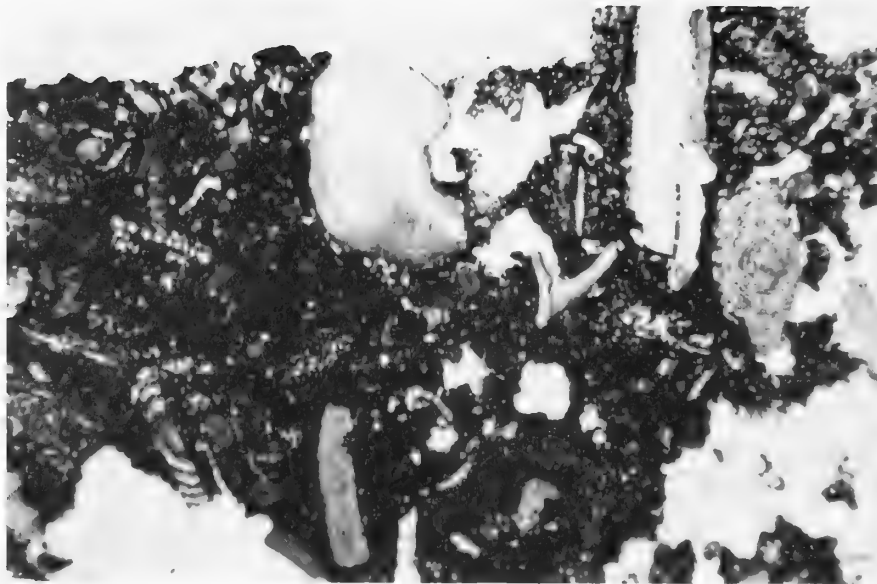


Fig. 6 Photomicrograph of cemented layer recovered in core S-6 showing *Halimeda*, mollusc and foraminifera grains in micritic cement and matrix. Field of view is 10 mm wide.

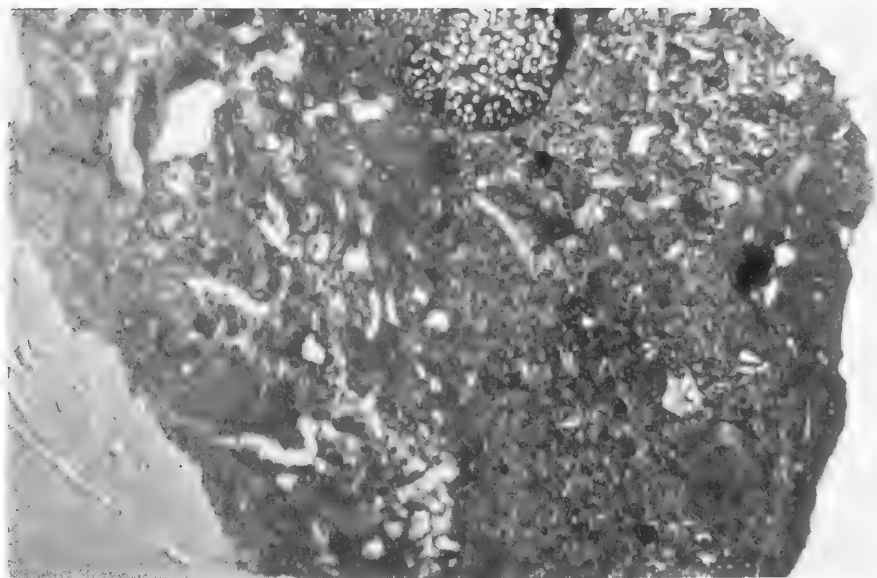


Fig. 7 Photomicrograph of limestone substrate below sand cay, showing *Halimeda* grain and bored and micritized probable *Porites* grain. *Halimeda* grain is 2 mm diameter.

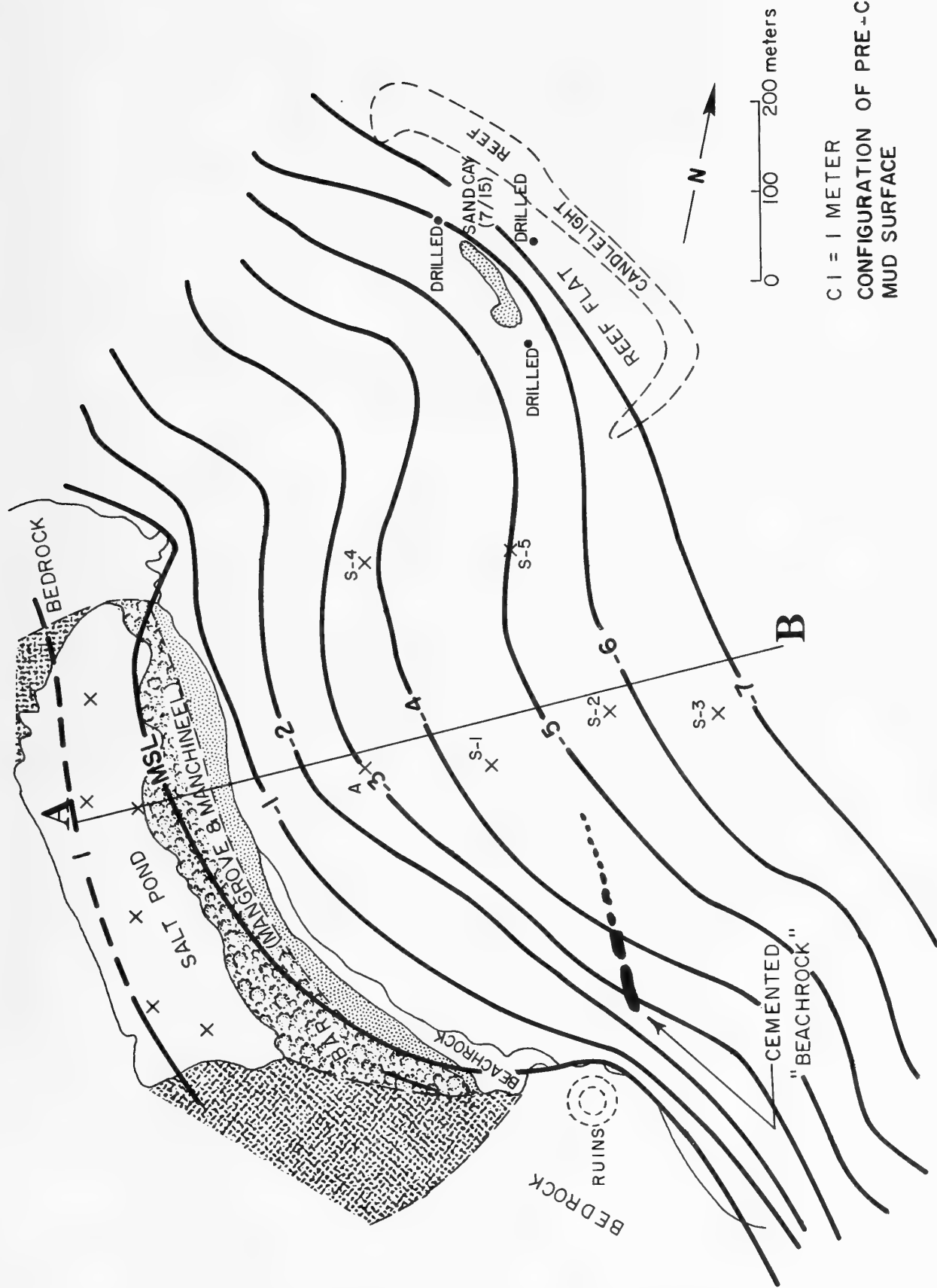


Fig. 8 Topography of mud surface, Coakley Bay, St. Croix.

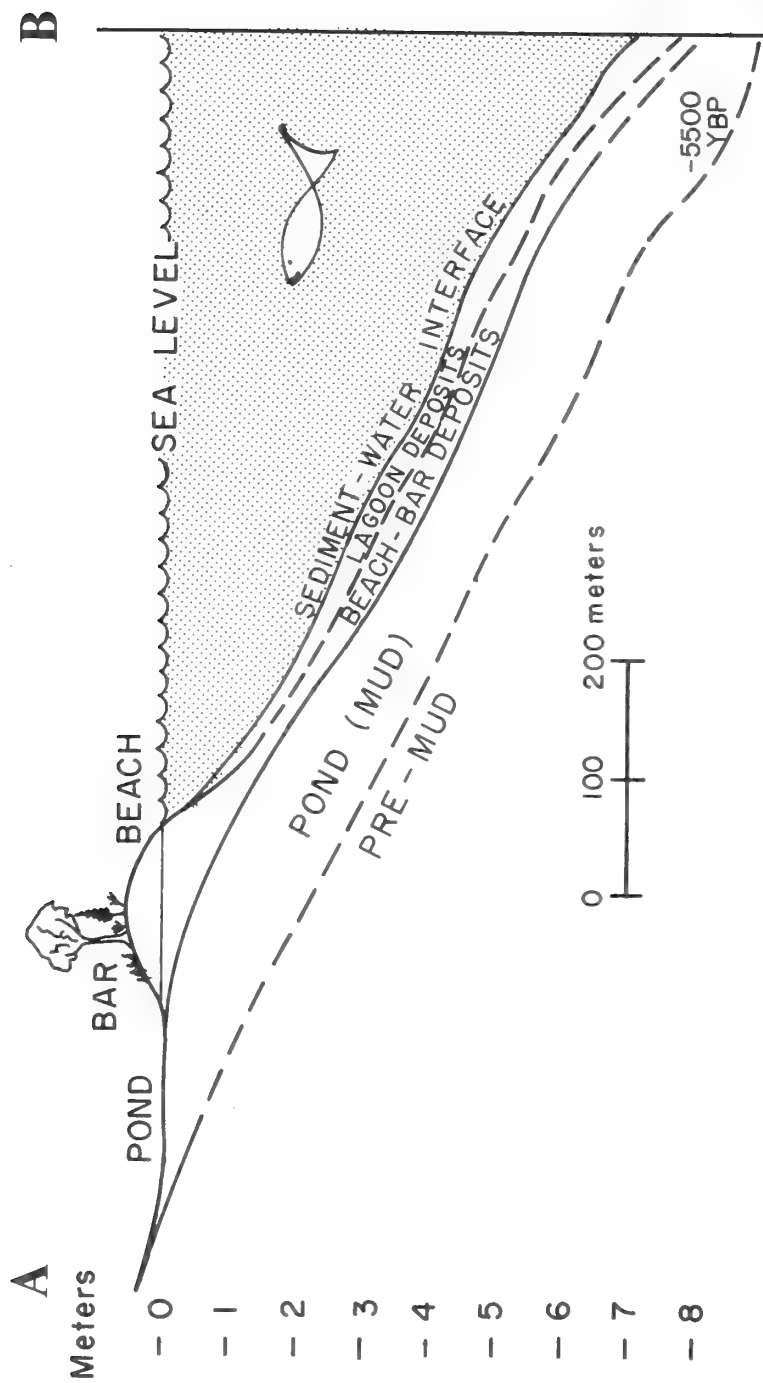


Fig. 9 Schematic cross-section through Coakley Bay showing stratigraphic relationships between modern and earlier sediments.

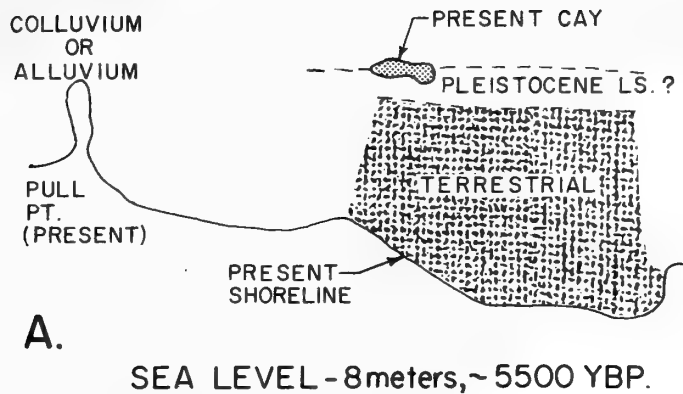
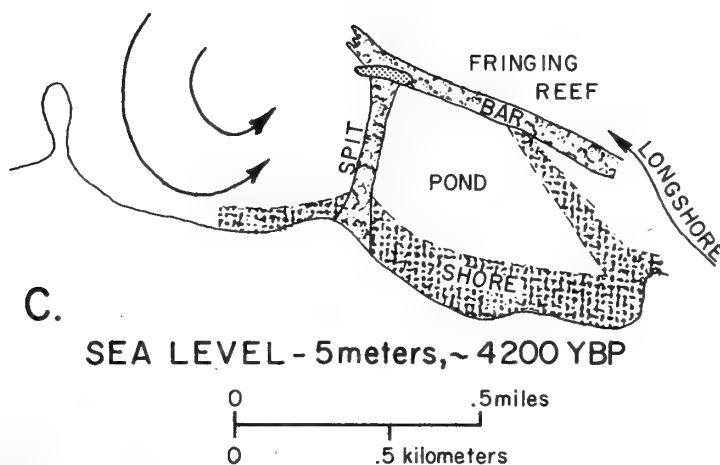
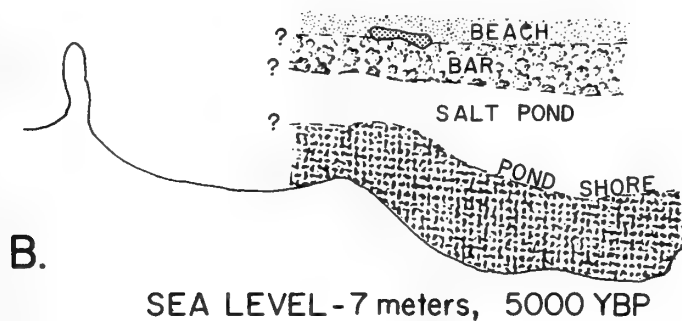
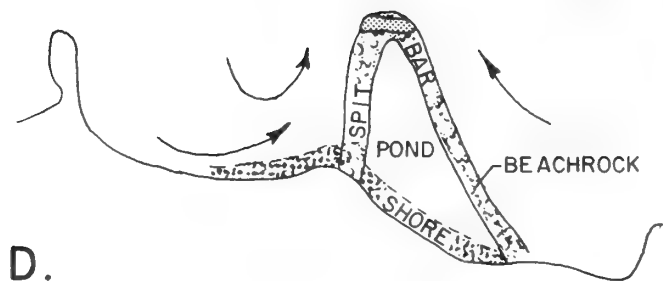


Fig. 10 Interpreted development stages for Sand Cay, Coakley Bay, and associated features. A. >5500 YBP. B. ~5000 YBP. C. ~4200 YBP. D. ~3000 YBP. E. Present.

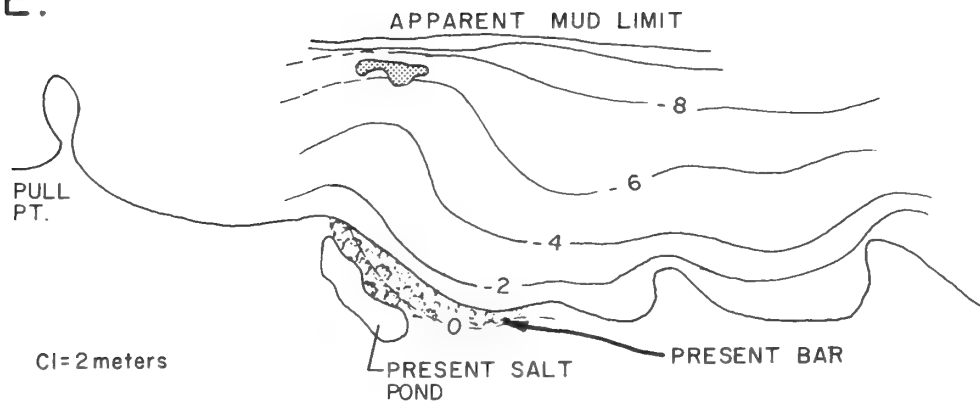




D.

SEA LEVEL -2 meters, 3000 YBP.

E.



0 0.5 miles
0 0.5 kilometers

**ATOLL RESEARCH BULLETIN
NO. 243**

**A PRELIMINARY LIST OF INSECTS OF DIEGO GARCIA
ATOLL, CHAGOS ARCHIPELAGO**

by A. M. Hutson

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A PRELIMINARY LIST OF INSECTS OF DIEGO GARCIA ATOLL, CHAGOS ARCHIPELAGO

by A. M. Hutson¹

INTRODUCTION

This paper presents a list of the insects collected by the author on Diego Garcia between March 19 and May 23, 1971, and discussion of earlier records. The circumstances of this visit are discussed in Hutson (1975). A general account of the geography and ecology of Diego Garcia is given in Stoddart & Taylor (1971). The intention of this paper is to give an idea of the composition of the insect fauna, to add to the previously recorded fauna such identifications as have been received to date and to make known what other material is available to specialists. All specimens are in the British Museum (Natural History). No attempt has been made to give details of locality, date, bionomics, etc. and numbers of specimens collected. Specimens were collected using hand techniques, at light and a small amount in a make-shift Herting Trap and water traps. The principal collecting sites were in the areas around Eclipse Point, Pte Marianne, De Moulin, Roche Point and East Point (see map in Hutson, 1975).

Other material, not examined in this study, was collected by Fehlmann in 1966 (see Stoddart, 1971) and by members of the U.S. Navy stationed on the atoll in 1971 (notably a dentist, Garry Miller). As yet unpublished records from other Chagos Archipelago islands were collected by M.J.D. Hirons et al. on Egmont Atoll in 1972-73, Eagle, Three Brothers and Danger Atolls in 1975 and elsewhere in 1978-79 during joint forces expeditions.

49 species of insect have been recorded from Diego Garcia and 113 from the Chagos Archipelago as a whole. All these records are discussed here. Where possible the nomenclature of these records has been brought up to date, but the identifications have not been checked except where stated. The author's interest in Diptera has probably given a bias to

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the collections made as well as to the results presented here. The previous major collection was by the Lepidopterist T. Bainbrigge Fletcher. Fletcher was on Diego Garcia for seven days of July, 1905 during the five weeks (May to July) that the Percy Sladen Trust Expedition was in the Chagos Archipelago. Of the 49 species previously recorded from Diego Garcia only 25 (51%) have been positively identified in the 1971 material. Similarly 49 (43%) of the 113 species previously recorded for the Chagos Archipelago as a whole have been identified in this material. More than 330 species were collected in 1971, but many of these still await identification.

THYSANURA

1 species unidentified

COLLEMBOLA

c.10 species unidentified

ODONATA

ANISOPTERA det. P.H. Ward

LIBELLULIDAE

Diplacodes trivialis (Rambur)
Pantala flavescens (Fabricius)
Trapezostigma limbata (Desjardins)

ZYGOPTERA det. P.H. Ward

COENAGRIIDAE

Agriocnemis pygmaea (Rambur)

Laidlaw (1907 recorded *Zyxomma seychellarum* Martin from Peros Banhos, *Orthetrum wrighti* (Selys) from Salomon, Peros Banhos and Diego Garcia, and *Ischnura senegalensis* (Rambur) (Agrionidae) from Diego Garcia. Champion (1913) re-identified the first two as *Zyxomma petiolatum* (Rambur) and *D. trivialis* respectively, and added *Tramnea limbata* Desjardins. Thus the present collection brings the total number of species to five for Diego Garcia and six for the Chagos.

ORTHOPTERA

TETTIGONIOIDEA det. J.A. Marshall

Euconocephalus chagosensis (Bolivar)

Gryllacrididae nymphs indet.

Bolivar (1912) described *Conocephaloides chagosensis* (now in the genus *Euconocephalus*) from Salomon and recorded *E. incertus* (Walker) (as *C. breviceps* Redtenbacher) from Salomon, Peros Banhos, Egmont and Diego Garcia.

GRYLLOIDEA det. J.A. Marshall

Ornebius validus (Bolivar)*Gryllodes sigillatus* (Walker)*Gryllotalpa* sp.

Bolivar (1912) described *Scottia chagosensis* (*Scottia* Bolivar preocc. = *Scottiola* Uvarov) from Salomon, and recorded *Curtilla* (= *Gryllotalpa*) *africana* (Pal. de Beauv.) from Peros Banhos and Egmont and *O. validus* from Salomon and Peros Banhos.

ACRIDIDAE det. L.M. Pitkin

Aiolopus simulatrix simulatrix Walker

Bolivar (1912) described *Aeolopus laticosta* from Salomon, Peros Banhos and Diego Garcia. This is now regarded as a synonym of *A. simulatrix*. ARDA (1961) records *A. savignyi* (Krauss), also a synonym of *A. simulatrix*, from Diego Garcia.

TETRIGIDAE det. J. Huxley

Paratettix chagosensis Bolivar

Bolivar (1912) described *P. chagosensis* from Diego Garcia.

DICTYOPTERA

BLATTODEA det. J.A. Marshall

Periplaneta americana (Linnaeus)*Periplaneta australasiae* (Fabricius)*Neostylopya rhombifolia* (Stoll)*Nauphoeta cinerea* (Olivier)*Leucophaea maderae* (Fabricius)*Pycnoscelus surinamensis* (Linnaeus)*Pycnoscelus indicus* (Fabricius)*Blattella germanica* (Linnaeus)*Margattea parvula* Bolivar

indet. nymphs

Bolivar (1924) recorded *B. germanica* from Salomon, *Margattea laxiretis* (described as a new species) from Salomon, *Periplaneta americana* from Peros Banhos, *P. australasiae* from Salomon and Diego Garcia and *P. surinamensis* from Diego Garcia and Peros Banhos. 9 of the 10 species recorded from the Chagos occur on Diego Garcia.

ISOPTERA

KALOTERMITIDAE det. R.M.C. Williams

<i>Cryptotermes dudleyi</i> Banks	at a light
<i>Glyptotermes</i> sp. nr. <i>scotti</i> (Holmgren)	trunk of rotting Cocos tree

RHINOTERMITIDAE det. R.M.C. Williams

<i>Prorhinotermes canalifrons</i> (Sjöstedt)	trunk of rotting Cocus tree, crown of fresh Cocos tree and at light.
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DERMAPTERA

CARCINOPHORIDAE det. A. Brindle

Anisolabis sp. ?nov.

CHELISOCHIDAE det. A. Brindle

Chelisoches morio (Fabricius)
Hamaxas sp. nov.

LABIIDAE

Labia curvicauda (Motschulsky)
sp. inde†.

Burr (1910) recorded *Borellia* [= *Euborellia*] *stali* (Dohrn) from Egmont and *Labidura riparia* (Pallas) from throughout the Chagos.

EMBIOPTERA

OLIGOTOMIDAE det. E.S. Ross

Oligotoma saundersii (Westwood)

PSOCOPTERA

indet. (c.10 species)

PHTHIRAPTERA

AMBLYCERA det. T. Clay

MENOPONIDAE

Austromenopon sp. from *Anous stolidus*

ISCHNOCERA det. T. Clay

PHILOPTERIDAE

Quadriceps separatus (Kellog & Kuwana) from *Anous stolidus*
Q. strepsilaris (Denny) from *Arenaria interpres*

Other unidentified lice were collected from *Acridotheres tristis* and *Streptopelia picturata*.

HEMIPTERA

HETEROPTERA det. P.S. Bloomfield

COREIDAE

1 sp. indet.

CYDNIDAE

1 sp. indet.

GERRIDAE

2 spp. indet.

LYGAEIDAE

4 spp. indet.

MIRIDAE

2 spp. indet.

PENTATOMIDAE

1 sp. indet.

REDUVIIDAE

1 sp. indet.

SALDIDAE

1 sp. indet.

Halobates alluaudi Bergroth was recorded without precise locality by Distant (1909, 1913). The Reduviid *Platymerus laevicollis* Distant was introduced to Diego Garcia in 1963 from East African stock in an attempt to control the Rhinoceros beetles, *Oryctes rhinocerus* (Linnaeus). 100 were released (Greathead, 1971), but there are no further records. The Reduviid mentioned for the present collection is a different species. No other Heteroptera have been recorded.

HOMOPTERA-AUCHENORHYNCHA det. P.S. Broomfield

CICADELLIDAE

5 spp. indet.

CIXIIDAE

1 sp. indet.

DELPACIDAE

5 spp. indet.

DERBIDAE

1 sp. indet.

12 species here, no previous records.

HOMOPTERA-STERNORHYNCHA

APHIDIIDAE det. V.F. Eastop

Aphis gossypii Glover on *Vernonia*

COCCIDAE det. D.J. Williams

Pulvinaria grabhami Cockerell on *Achyranthes canescens*

DIASPIDIDAE det. D.J. Williams

Hemiberlesia lataniae (Signoret) on *Morinda citrifolia*

PSEUDOCOCCIDAE det. D.J. Williams

Planococcus citri-group on *Morinda citrifolia*
Pseudococcus citriculus Green on *Morinda citrifolia*

PSYLLIDAE det. D. Hollis

Leptynoptera sulphurea Crawford on *Calophyllum inophyllum*
Mesohomotoma hibisci (Froggatt) on *Hibiscus tiliaceus*

P. citri (Risso) was recorded from Diego Garcia from *Ficus* sp. by Green (1907) in the genus *Dactylopius* and by Mamet (1941) in the genus *Pseudococcus*. The group of species to which this belongs is currently under review and it is likely that the species on Diego Garcia is not true *citri*. Green also records *Lecanium* (=Saissetia) *oleae* (Olivier) (Coccidae) from "figuier des Banians" on Peros Banhos and Mamet (1941, 1943) recorded this species, *Ferrisia virgata* (Cockerell) (Pseudococcidae) and the Diaspidids *Aspidiella sacchari* (Cockerell), *Odonaspis ruthae* Kotinsky and *Pinnaspis aspidistrae* (Signoret). Greathead (1971) discusses the introduction of two species of Coccinellid beetle to control scale insects on Coconut and other crops. The scale insects were not named, but Orian (1959) listed *Aspidiotus destructor* Signoret, *Chrysomphalus ficus* Ashmead, *Pseudococcus adonidis* (Linnaeus) (=longispinus (Targioni Tozzetti) and *Pseudococcus* sp. as pests of coconut. Many palms were felled while the author was on the island, but no obvious damage by scale insects was evident.

Thus the present collection brings the published list for the Chagos to 12 species of Coccoidea. No other Sternorhyncha have been recorded previously so that the total for the whole group is 15.

THYSANOPTERA

PHLAEOTHIRIPIDAE det. B.R. Pitkin

Haplothrips gowdeyi (Franklin) on *Vernonia*, grasses, etc.

NEUROPTERA

CHRYSOPTIDAE

Chrysopa sp.

Esben-Petersen (1927) described *Chrysopa rutila* as a new species from Salomon and Peros Banhos. This is now considered a synonym of the widespread *C. boninensis* Okamoto.

COLEOPTERA

BOSTRYCHOIDEA

LYCTIDAE det. E.R. Peacock

Lyctus brunneus Stephens

CARABOIDEA

CARABIDAE det. I.H. Davidson

indet.

ARDA (1961) states that the Carabid *Scarites madagascariensis* Dejean was being collected in Madagascar for despatch to Diego Garcia for control of Rhinoceros Beetle, *Oryctes rhinocerus* (Linnaeus), but I have not been able to establish whether this was actually accomplished and none was found in 1971.

DYTISCIDAE

Scott (1912) recorded *Bidessus thermalis* Germar from Diego Garcia, but no Dytiscids were found in 1971.

CHRYSOMELOIDEA

CERAMBYCIDAE det. I.H. Davidson

Cerambycinae indet.
Lamiinae indet.

Aurivillius (1922) recorded *Coptops aedificator* (Fabricius) from Salomon and Diego Garcia.

CLEROIDEA

CLERIDAE det. I.H. Davidson

Necrobia rufipes (Degeer)

The presence of this species on Diego Garcia was inferred by Orian (1959).

CUCUJOIDEA

ADERIDAE det. I.H. Davidson

Xylophilus spp. (3)

ANTHICIDAE det. I.H. Davidson

Anthicus nr. *andreae* Laf.

CERYLONIDAE det. I.H. Davidson

Euxestus ?basalis (Motschulsky)

Arrow (1922) recorded *E. parki* Wollaston from Egmont.

COCCINELLIDAE det. R.D. Pope

Chilocorus nigritus (Fabricius)
Coccinella repanda Thundberg var.
Platynaspis capicola Crotch
Scymnus (s.s.) sp.

C. nigritus and a *Scymnus* sp. were introduced to control scale insects on Coconut and other crops (Greathead, 1971). 2000 *Chilocorus* and 150 *Scymnus* were liberated in 1956 and a further shipment of *Chilocorus* in 1959. The only other Coccinellids recorded are *Menochilus sexmaculatus* (Fabricius) (in Chilomenes) recorded by Sicard (1912) from Salomon, Peros Banhos and Diego Garcia, and *C. repanda* recorded in ARDA (1961).

COLYDIIDAE det. I.H. Davidson

Colibicus nr. *specialis* Grouvelle
Ocholissa sp.
Trachypholis sp.
 indet.

CORYLOPHIDAE det. I.H. Davidson

indet.

CRYPTOPHAGIDAE det. I.H. Davidson

indet.

CUCUJIDAE det. I.H. Davidson

Psammoecus sp.

ENDOMYCHIDAE det. I.H. Davidson

Trochoideus desjardinsii Guérin

This was recorded from Egmont by Arrow (1922).

INOPEPLIDAE det. E.R. Peacock

Inopeplus sp.

NITIDULIDAE det. E.R. Peacock

Cybocephalus sp.

indet.

Grouvelle (1913) recorded *Carpophilus hemipterus* Linnaeus from Diego Garcia.

OEDEMERIDAE det. I.H. Davidson

Ananca aldabrana Champion
A. scabripennis Champion
A. ? var. of *scabripennis* Champion

RHIZOPHAGIDAE det. E.R. Peacock

Monotoma madagascariensis Grouvelle

TENEBRIONIDAE det. M.J.D. Brendell

Gonocephalum spp. (2)

indet.

CURCULIONOIDEA

ANTHRIBIDAE det. I.H. Davidson

indet.

APIONIDAE det. R.T. Thompson

Cylas formicarius Fabricius

CURCULIONIDAE det. R.T. Thompson

CURCULIONINAE det. R.T. Thompson

Cratopus adpersus Waterhouse

Microtrupis sp.

Mylocerus dentifer Fabricius var.

Pentarthrum sp.

Proeces depressus (Wollaston)

Stenotrupis sp.

?*Stenotrupis* sp.

SCOLYTINAE det. E.A.J. Duffey

Hypothenemus sp.

Xyleborus perforans Wollaston

Champion (1914) recorded *C. adpersus* from Salomon, Peros Banhos and Egmont, and *Sternochetus mangiferae* (Fabricius) (in the genus *Cryptorrhynchus*) without locality details.

DRYOPOIDEA

PTYLODACTYLIDAE det. I.H. Davidson

indet.

ELATEROIDEA

ELATERIDAE det. C.M.F. von Hayek

Lacon modestus (Boisduval)

Melanoxanthus sp.

Fleutiaux (1923) recorded *Melanoxanthus puerulus* Candèze var. *cribricollis* Fleutiaux from Peros Banhos.

EUCNEMIDAE

Fleutiaux (1923) described *Fornax puncticeps* (in the family Melasidae) from the Seychelles and Egmont, but no Eucnemids were collected in 1971.

HYDROPHILOIDEA

HYDROPHILIDAE det. I.H. Davidson

Paromicrus atomus Scott
indet.

HISTEROIDEA

HISTERIDAE

Regular shipments of *Hololepta quadridentata* Fabricius and *Plaesius javanus* Erichson were introduced from Trinidad to control the Rhinoceros beetle, *Oryctes rhinocerus* (Linnaeus), in 1959 (Greathead, 1971). They were seen in 1960 but there has been no evidence of their establishment and no Histerids were collected in 1971.

SCARABAEOIDEA

SCARABAEIDAE

APHODINAE det. I.H. Davidson

indet.

CETONIINAE det. M.E. Bacchus

Protaetia fusca (Herbst)

DYNASTINAE det. I.H. Davidson

Oryctes rhinocerus (Linnaeus)

RUTELINAE det. I.H. Davidson

Adoretus versutus Harold

Scott (1912) recorded *A.versutus* from Egmont, *Saprosites laticeps* (Fairmaire) from Egmont and *Oxycetonia versicolor* Fabricius from Peros Banhos. The Rhinoceros Beetle, *Oryctes rhinocerus*, was not noted then but was such a pest of coconuts by the 1950's that various attempts were made to control it. Greathead (1971) discusses the attempts with biological control and these are discussed under Reduviid Hemiptera,

Scoliid wasps and Histerid beetles. See also under Carabidae. None of these control methods seems to have had any great impact on the beetle.

STAPHYLINOIDEA

STAPHYLINIDAE det. P.M. Hammond

Acanthoglossa brachycera Kraatz
Aleochara puberula Klug
Aleochara sp.
Bledius sp.
Carpelimus sp.
Coenonica puncticollis Kraatz
Coproporus sp.
Lithocharis nigriceps Kraatz
Lithocharis sp.
Osorius sp.
Philonthus spp. (2)
Schistogenia crenicollis Kraatz
Scopaeus sp.
Thinodromus chagosanus (Bernhauer)

Bernhauer (1922) described *Thinodromus chagosanus* (in the genus *Troglophloeus*) from Diego Garcia.

SIPHONAPTERA

PULICIDAE det. A.M. Hutson

Ctenocephalides f. felis (Bouché)

DIPTERA

NEMATOCERA

CECIDOMYIIDAE det. K.M. Harris

CECIDOMYIINAE

Allobremia sp. nr. *upolui* Barnes
Lestodiplosis sp.
Lestodiplosini indet.
 spp. indet.

IESTREMIINAE

Lestremia sp.
Peromyia sp. nr. *seychellensis* Kieffer

PORRICONDYLINAE

Asynapta sp.
Porricondyla sp.

CERATOPOGONIDAE det. R.P. Lane

Atrichopogon sp.
Bezzia sp.
Dasyhelea spp. (3)
Forcipomyia spp. (2)

CHIRONOMIDAE det. P.S. Cranston

CHIRONOMINAE

Tanytarsini indet.

ORTHOCLADIINAE

Pseudosmittia sp.
 sp. indet.

CULICIDAE det. G.B. White

Aedes albopictus (Skuse)
Culex quinquefasciatus Say

Theobald (1912) recorded *Aedes albopictus* (Skuse) (as *Stegomyia scutellaris* (Walker) from Peros Banhos (see also Mattingly & Brown, 1955). Lambrecht & Van Someren (1971) found *A. albopictus* and *C. quinquefasciatus* (as *pipiens* spp. *fatigans* Wiedemann) abundant on Diego Garcia, Salomon and Peros Banhos. They also reported *Aedes aegypti* (Linnaeus) on Diego Garcia and Salomon. It is interesting to note that the specimens collected (in 1969) were of the typical form rather than the form *queenslandensis* which is the dominant form in the Seychelles and Africa. It was searched for around settlements in 1971 and its apparent absence is curious.

MYCETOPHLIDAE det. A.M. Hutson

Allactoneura argenteosquamosa (Enderlein)

PSYCHODIDAE det. D.A. Duckhouse

Clogmia albipunctata (Williston)
Psychoda alternata Say
P. savaiiensis Edwards

SCATOPSIDAE det. A.M. Hutson

Holoplagia guamensis (Johannsen)

SCIARIDAE det. W.A. Steffan

Bradysia tritici Coquillett
Corynoptera latistylata Hardy
 indet.

TIPULIDAE det. A.M. Hutson

Gonomyia (Lipophleps) ornatipes (Brunetti)
Limonia (Atypophthalmus) umbrata (de Meijere)

BRACHYCERA

ASILIDAE det. S.J. Chambers

Clinopogon sp.

Lamb (1922) recorded *Stichopogon scalaris* Bigot (now a species of *Sarapogon*) from Salomon, Peros Banhos and Diego Garcia, but this was a misidentification of *Clinopogon nicobarensis* (Schiner) and is likely to be the same species as the species collected in 1971.

DOLICHOPODIDAE det. C.E. Dyte

Argyrochlamys impudicus Lamb
Chrysosoma leucopogon (Wiedemann)
Chrysotus pallidipalpus van Duzee
Sciapus librativertex Lamb
Sciapus sp. nov.

Lamb (1922) recorded *C. leucipogon* (in the genus *Psilopus*) from Salomon and Peros Banhos.

CYCLORRHAPHA

ASCHIZA

PHORIDAE det. K.G.V. Smith

Chonocephalus similis Brues
Megaselia sp.
 indet.

SYRPHIDAE

No Syrphidae were collected in 1971. Lamb (1922) recorded *Ornidia obesa* Fabricius (in the genus *Volucella*) from Diego Garcia and *Ischiodon aegyptium* (Wiedemann) (in the genus *Xanthogramma*) from Peros Banhos. The absence of *O. obesa* in 1971 is notable since this is such a large species which is very obvious in the field. The specimen of *Ischiodon* from Peros Banhos has been re-identified by K.G.V. Smith as the Oriental *scutellaris* Fabricius and not the African *aegyptium*.

SCHIZOPHORA

PLATYSTOMATIDAE det. B.H. Cogan

Plagiostenopterina ruficeps Hendel
Scholastes cinctus Guerin

Lamb (1914) recorded *S. cinctus* from Salomon and Diego Garcia.
 ARDA (1961) records *S. vicarius* Hendel, but doubtless all these records refer to the same species.

OTITIDAE det. B.H. Cogan

Physiphora demandata (Fabricius)
Pseudeuxesta prima Osten-Sacken

Lamb (1914) recorded *Physiphora azurea* (Hendel) (in the genus *Chrysomyza*) from Salomon.

SEPSIDAE det. J. Zуска

Australosepsis niveipennis Becker
Sepsis lateralis Wiedemann
Sepsis sp.

LAUXANIIDAE det. B.H. Cogan

Sapromyza spp. (2)

SPHAEROCERIDAE det. J.P. Dear

Leptocera (Coproica) ferruginata Stenhammer
L. (C.) hirtula Rondani
L. (Poecillosoma) angulata Thomson
L. (Limosina) bifrons Stenhammer
L. (L.) sp. nr. *moesta* Villeneuve

LONCHEIDAE det. B.H. Cogan

Lamprolonchaea aurea Macquart
Lonchaea spp. (2)

AGROMYZIDAE

No Agromyzidae were collected in 1971, but Lamb (1912) recorded an *Agromyza* sp. from Salomon.

XENASTEIDAE det. D.E. Hardy

Xenasteia similis Hardy, described from the present collection by Hardy (1980).

EPHYDRIDAE det. B.H. Cogan

Allotrichoma sp.
Hecamedia lacteipennis Lamb
Nostima striata Lamb
Nostima sp.
Placopsidella cyanocephala Kertesz
Scatella sp.

DROSOPHILIDAE

Mycodrosophila sp. det. L. Tsacas
Zaprionus ?vittiger Coquillett det. B.H. Cogan
Drosophila spp. (more than 4) det. B.H. Cogan

MILICHIIDAE det. B.H. Cogan

?*Desmometopa* sp.

CANACEIDAE det. B.H. Cogan

Nocticanace ?mahensis Lamb

CHLOROPIDAE det. B.H. Cogan

Cadrema nigricornis Thomsen
C. pallida Loew
C. pallida var. *bilineata* de Meijere

MUSCIDAE det. A.C. Pont

Atherigona orientalis Schiner
A. oryzae Malloch
Musca sorbens Wiedemann
Ophyra chalcogaster Wiedemann
Stomoxys calcitrans Linnaeus

CALLIPHORIDAE det. J.P. Dear

Chrysomya megacephala (Fabricius)
Rhinia apicalis Wiedemann

Stein (1910) recorded *R. apicalis* without details of locality and Bezzi quoted (1923) this record and recorded *C. megacephala* and *Lucilia argyrocephala* Macquart (sic) from Salomon. *L. argyrocephala* is a synonym of *L. cuprina* (Wiedemann).

SARCOPHAGIDAE det. J.P. Dear

Boettcherisca peregrina Robineau-Desvoidy
Sarcophaga (Curranella) tibialis Macquart
S. (Thyrsoctema) sp.

Bezzi (1923) recorded *Sarcophaga ruficornis* Wiedemann and *S. dux* Thomson from Peros Banhos. *S. dux* is a misidentification for *B. peregrina*.

TACHINIDAE det. R.W. Crosskey

Therobia abdominalis (Wiedemann)

LEPIDOPTERA

LYCAENIDAE det. C. Huggins

Petralaea dana de Niceville

adults on *Terminalia* & *Morinda*

NYMPHALIDAE det. A.M. Hutson

Hypolimnas sp.

A single ♂ *Hypolimnas* was seen for several days in various scrubby bushes. It was thought to be *misippus* Linnaeus, but may have been *bolina* Linnaeus.

Bourne (1886) records *Vanessa 'bolini'* from Diego Garcia, but Poulton (1924) re-identified his specimen as *misippus*; this appears to be the only substantiated record of *misippus* from the Chagos. *H. bolina* was recorded by Fletcher (1910a) from Salomon, Peros Banhos, Diego Garcia and Egmont Atolls. Fletcher, and later Walker (1920), noted differences between specimens from Chagos and elsewhere and Poulton (1924) described this as a separate subspecies, *euphonoides*.

Bourne (op. cit.) also refers to seeing "one individual of *Oenone*". This may refer to *Junonia oenone* Linnaeus, widely recorded around the western Indian Ocean, but with no other records for the Chagos. Fletcher (op. cit.) records *J. villida* Fabricius (as *vellida*) from throughout the Chagos. On the basis of Fletcher's specimens Watkins (1925) described the subspecies *chagoensis*. Thus five species of butterfly have been recorded from Chagos with two endemic subspecies, but the status of some needs confirmation.

ARCTIIDAE det. M.A. Lane

ARCTIINAE

Utetheisa pulchelloides Hampson

LITHOSIINAE

Eilema spp. (?2)

Fletcher (1910a) recorded *U. pulchelloides* from Salomon, Peros Banhos and Diego Garcia.

GEOMETRIDAE det. D.S. Fletcher

Chloroclystis immixtaria Walker
Pyrrhorachis p. pyrrhogona Walker
Scopula actuaria Walker

NOCTUIDAE det. A.H. Hayes (except where stated otherwise)

ACONTIINAE

Ilattia octo (Guenée)
Berresa natalis (Walker)
Porphyrinia cochylioides (Guenée)

ACRONICTINAE

Callopietria maillardi Guenée
Chasmina tibialis Fabricius
Prospalta capensis Guenée
Spodoptera litura Fabricius
S. mauritia acronyctoides Guenée (det. I.W.B. Nye)

CATOCALINAE

Mocis frugalis Fabricius

OPHIDERINAE

Anomis sabulifera Guenée

SARROTHRIPINAE

Characoma nilotica Rogenhofer

Fletcher (1910a) recorded six species of Noctuidae and 11 are listed here. The only two species occurring in both lists are *C. maillardi* which Fletcher recorded (in the genus *Eriopus*) from Salomon and *M. frugalis* which Fletcher recorded (in the genus *Remigia*) from Diego Garcia. The other species recorded by Fletcher are *Spodoptera littoralis* (Boisduval) (in the genus *Prodenia*) from Salomon, Peros Banhos and Diego Garcia; *Thias honesta* Hübner (in the genus *Ophiusa*) from Peros Banhos; *Chrysodeixis chalcytes* Esper (in the genus *Plusia*) from Egmont and *Anomis erosa* Hübner (in the genus *Cosmophila*) from Salomon. Thus 12 species are recorded from Diego Garcia of 15 for the Chagos as a whole.

SPHINGIDAE det. A.H. Hayes

Acherontia lachesis Fabricius
Agrius convulvuli Linnaeus
Macroglossum corythus Walker

Fletcher (1910a) recorded *A. lachesis* from Peros Banhos and Diego Garcia and *M. corythus* from Salomon and Peros Banhos. He also recorded *Cephanodes picus* Cramer and *Hippotion velox* Fabricius both from Peros Banhos. Orion (1959) recorded *A. convulvuli* (in the genus *Herse*) from Diego Garcia. Thus three species are recorded from Diego Garcia and five from the Chagos as a whole.

PTEROPHORIDAE det. M. Shaffer

Platyptilia pusillidactyla ?Walker

Fletcher (1910a) recorded *Trichoptilus defectalis* Walker from Salomon and Peros Banhos and later (1910b) transferred it to the genus *Buckleria*.

PYRALIDAE det. M. Shaffer

GALLERIINAE

Galleria mellonella Linnaeus

PHYCITINAE

Etiella grisea ?grisea Hampson

Phycita sp. nr. *jasminophaga* Hampson

PYRALINAE

Endotricha m. mesenterialis Walker

PYRAUSTINAE

Aethaloessa c. calidalis Guenée

Antiercta ornatalis Duponchel

Diaphania indica Saunders

Eurrhyarodes tricoloralis Zeller

Herpetogramma licarsisalis Walker

Hymenia recurvalis Fabricius

Lamprosema salomonalis (Fletcher)

Loxostege massalis Walker

Marasmia poeyalis Boisduval

Parotis suralis Lederer

Sufetula minimalis Fletcher

Fletcher (1910a) recorded *E. mesenterialis* from Salomon, *D. indica* (in the genus *Glyphodes*) from Peros Banhos and described *L. salomonalis* (in the genus *Nacoleia*) from Salomon. 9 other species not collected in 1971 were *Culladia admigratella* Walker (Diego Garcia), *Endotricha chagosalis* (described as a new species from Salomon, but also seen on Diego Garcia), *Bradina admixtalis* Walker (Salomon), *Mabra eryxalis* Walker (Egmont), *Zinckenia fascialis* Cramer (Salomon, Peros Banhos and Diego Garcia), *Marasmia venilialis* Walker (Salomon and Peros Banhos), *Syngamia floridalis* Zeller (Salomon), *Nacoleia niphealis* Walker

(Salomon and Peros Banhos) and *N. chagosalis* (described as a new species from Salomon and Egmont).

Thus 18 species are recorded from Diego Garcia and 24 from the Chagos as a whole.

TORTRICIDAE det. J.D. Bradley

Cryptophlebia encarpa Meyrick

The 1971 material also included about 30-35 spp in the following families (det. G.S. Robinson):

COSMOPTERIGIDAE

GELECHIIDAE

GLYPHIPTERIGIDAE

GRACILLARIIDAE

STATHMOPODIDAE

TINEIDAE

TORTRICIDAE

Meyrick (1911) recorded the Eucosmid *Argyroploce aprobola* Meyrick, the Cosmopterygid *Stagmatophora tentoria* as a new species and the Tineid *Dacadarchis molynta* as a new species. All were recorded from the Seychelles, with further specimens (without precise locality details) from the Chagos.

HYMENOPTERA

ACULEATA

APIDAE det. G.R. Else

Apis mellifera Linnaeus

Cameron (1907) recorded *Apis mellifera* (as *unicolor* Latreille) from Peros Banhos and Diego Garcia.

MEGACHILIDAE det. G.R. Else

Megachile sp.

XYLOCOPIDAE det. G.R. Else

Xylocopa sp.

EUMENIDAE det. E.A. Jarzembowsky

Euodynerus trilobus (Fabricius)
Eumeninae indet.

Subancistrocerus sichelii Sauss

Cameron (1907) described *Odynerus caeocephalus* from Salomon, Peros Banhos and Egmont, and *O. chagosensis* from Salomon and Peros Banhos. Both these species are now considered synonyms of *E. trilobus*.

FORMICIDAE det. B. Bolton

Cardiocondyla spp. (2)
Tapinoma sp.
spp. indet (c.6)

Forel (1907) recorded *Paratrechina bourbonica* (Forel) (in the genus *Prenolepis*) and *Camponotus maculatus* (Fabricius) (with two subspecies: *boivini* Forel and *fulvus* Emery) without details of locality. Orion (1959) recorded *Technomyrmex detorquens* (Walker) from Diego Garcia, but this probably refers to *T. albipes* (Smith).

SCOLIIDAE det. M.C. Day

Scolia ruficornis Fabricius

S. ruficornis was introduced (Greathead, 1971) from Zanzibar in 1951 to help control the Rhinoceros Beetle, *Oryctes rhinoceros* (Linnaeus). 89 ♀ and 6 ♂ were originally introduced and it was stated to be established in 1956 but ineffective — it is still well established and ineffective. 100 ♀ *S. oryctophaga* Coquillett were also introduced from Mauritius prior to 1951 for the same purpose, but they have not been recorded since.

SPHECIDAE det. C.R. Vardy

Ampulex sp.
Chalybion sp.
Pison sp.
Trypoxylon sp.

Cameron (1907) recorded *Chalybion bengalense* (Dahlbom) (in the genus *Sceliphron*) and *Ampulex compressa* (Fabricius) both from Salomon and Peros Banhos. Turner (1911) also recorded these species without locality details.

VESPIDAE det. O.W. Richards

Polistes olivaceus (Degeer)

Cameron (1907) recorded *Polistes hebraeus* Fabricius from Salomon and Diego Garcia, but Meade-Waldo (1912) considered this a misidentification of *P. macaensis* Fabricius. Both these species are now regarded as synonyms of *olivaceus* (Degeer).

PARASITICA

AGAONIDAE det. L. Rogers

indet.

APHELINIDAE det. L. Rogers

indet.

BRACONIDAE det. T. Huddleston

Spathius sp.

Cameron (1907) described *Tolbia scaevolae* from Salomon.

CERAPHRONIDAE det. N. Fergusson

indet. (1 sp.)

EUCARITIDAE

No Eucharitids were collected in 1971, but Cameron (1907) described *Stibula insularis* (in the family Chalcididae) from Egmont.

DIAPRIIDAE det. N. Fergusson

indet. (3 spp.)

ELASMIDAE det. L. Rogers

indet.

ENCYRTIDAE det. J. Noyes

Homalotylus sp.

EULOPHIDAE det. L. Rogers

indet.

EVANIIDAE det. M.G. Fitton

Evania sp.

Cameron (1907) recorded *Evania appendigaster* Linnaeus from Peros Banhos, Diego Garcia and Egmont.

ICHNEUMONIDAE det. M.G. Fitton

Enicospilus sp.

Cameron (1907) described *Echthromorpha latibalteata* from Peros Banhos. Morley (1912) considered this (by a lapsus as "*laeva* Cameron") to be a synonym of *notulatoria* (Fabricius). *E. notulatoria* is regarded as a synonym or subspecies of *agrestoria* (Swederus).

SCELIONIDAE det. N. Fergusson

indet. (3 spp.)

SUMMARY

Table 1 summarises, by order, the known fauna of the Chagos Archipelago with special reference to Diego Garcia.

Stoddart (1971) discusses earlier comparisons of the fauna of the Chagos and the Maldives. Since so little work has been done on either group, but particularly in the Maldives, there no longer seems any relevance in such a comparison. Neither is it possible to discuss in detail the origins of the fauna of these islands. Many of the species listed are common widely distributed species or species known from more restricted neighbouring faunas such as those of Seychelles, or Oriental or Afrotropical Regions, but these are likely to be the most readily recognisable and until some of the larger orders can be worked out completely it is only possible to surmise the obvious — that the fauna is more Oriental biased. The unidentified material includes many undescribed species, but it is unlikely that the Chagos Archipelago will have a substantial endemic fauna — of the 16 species described as new from the Chagos alone, 5 have been synonymised with other mainland species, 2 are still recognised as valid species, but are now known to have a much wider distribution and 9 have not been recorded subsequently (Table 2). Included in the latter are the two butterflies, *Hypolimnas bolina euphonoides* Poulton and *Junonia villida chagoensis* Watkins, which are currently regarded as valid endemic subspecies.

Of the species formerly recognised from these islands (113 from the Chagos as a whole, 49 from Diego Garcia) it is interesting that only 49 (43%) of the Chagos fauna and 25 (51%) of the Diego Garcia fauna was collected in 1971. Notable absentees were the two endemic butterflies mentioned above and the Diptera *Ornidia obesa* and *Aedes aegypti*. It is possible that this visit was not at the best time of year. The relatively small overlap of species recognised previously and found in 1971 suggests a much larger fauna for these islands, despite the restrictions imposed by their size, position and available habitat. Within the island group the proportion of insects recorded in 1971 and previously recorded from Diego Garcia is so much higher than that previously recorded for the Chagos as a whole that it is likely that there are good faunal differences between the islands, but

Table 1. Numbers of species of insects previously recorded from the Chagos Archipelago, with special reference to Diego Garcia, compared with the 1971 collection.

	Previously recorded from Chagos...	...but not collected 1971	Previously recorded from Diego Garcia...	...but not collected 1971	Collected Diego Garcia 1971	Total for Diego Garcia	Total for Chagos Arch.
Thysanura	0	0	0	0	1	1	1
Collembola	0	0	0	0	?	?	?
Odonata	4	2	2	1	4	5	6
Orthoptera	7	2	3	1	7	8	9
Dictyoptera	5	1	2	0	9	9	10
Isoptera	0	0	0	0	3	3	3
Dermoptera	2	2	?1	?1	5	?6	7
Embioptera	0	0	0	0	1	1	1
Psocoptera	0	0	0	0	c.10	c.10	c.10
Phthiraptera	0	0	0	0	5+	5+	5+
Hemiptera	11	10	5	4	32	36	42
Thysanoptera	0	0	0	0	1	1	1
Neuroptera	1	?0	0	0	1	1	1
Coleoptera	21	11	12	6	65+	71+	76+
Siphonaptera	0	0	0	0	1	1	1
Diptera	15	7	6	2	87+	89+	94+
Lepidoptera	32	22	12	7	69+	76+	91+
Hymenoptera	15	7	6	2	35+	37+	42+
Totals	113	64	49	24	336+	370+	400+

Table 2. The current status of species of insects originally described only from Chagos Archipelago.
(names listed in original combination).

<i>Conocephaloides chagosensis</i> Bolivar	(Orthoptera)	Valid species only known from Chagos, now in <i>Euconocephalus</i>
<i>Scottia chagosensis</i> Bolivar	(Orthoptera)	no further records, ? valid species, now in <i>Scottiola</i>
<i>Aeolopus laticosta</i> Bolivar	(Orthoptera)	= <i>A. simulatrix</i> Walker, widespread e.Africa, se Palaearctic, Orient.
<i>Paratettix chagosensis</i> Bolivar	(Orthoptera)	valid species, recorded Seychelles, Madagascar
<i>Margattea laxiretis</i> Bolivar	(Dictyoptera)	no further information
<i>Chrysopa rutila</i> Esben-Petersen	(Neuroptera)	= <i>C. boninensis</i> Okamoto, widespread Old World
<i>Fornax puncticeps</i> Fleutiaux	(Coleoptera)	no further information
<i>Trogophloeus chagosanus</i> Bernhauer	(Coleoptera)	no further records, now in <i>Thinodromus</i>
<i>Hypolimnas bolina euphonoides</i> Poulton	(Lepidoptera)	no further records, but regarded as valid endemic subspecies
<i>Junonia villida chagosensis</i> Watkins	(Lepidoptera)	no further records, but regarded as valid endemic subspecies
<i>Endotrichia chagosalis</i> Fletcher	(Lepidoptera)	no further records, now in <i>Sufetula</i>
<i>Nacoleia chagosalis</i> Fletcher	(Lepidoptera)	recorded Thailand, ? south India, now in <i>Lamprosema</i>
<i>Nacoleia salomonalis</i> Fletcher	(Lepidoptera)	no further records, now in <i>Lamprosema</i>
<i>Odyneus caenocephalus</i> Cameron	(Hymenoptera)	= <i>Euodynerus trilobus</i> Fab., widespread
<i>Odynerus chagosensis</i> Cameron	(Hymenoptera)	= <i>Euodynerus trilobus</i> Fab., widespread
<i>Echthromorpha latibalteata</i> Cameron	(Hymenoptera)	= <i>E. notulatoria</i> Fab., widespread
<i>Stibula insularis</i> Cameron	(Hymenoptera)	no further information

it seems unlikely that there is any strong change in diversity through the island chain linked with distance from the mainland. The disturbance by humans of the three major islands has been great, but very few species are recorded that would not have been able to reach there by more natural devices. It would be interesting to see whether recent changes in land use with concomitant changes in origin of visiting transport has produced any changes in the fauna or flora.

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**THE COMMUNITY STRUCTURE OF THE FRINGING
CORAL REEF, CAPE RACHADO, MALAYA**

by Goh Ah Hong and A. Sasekumar

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THE COMMUNITY STRUCTURE OF THE FRINGING CORAL REEF, CAPE RACHADO, MALAYA

by Goh Ah Hong and A. Sasekumar¹

ABSTRACT

Live coral cover was low (32.9%) on a belt transect 87 meters long and one metre wide, on the coral reef at Cape Rachado, Port Dickson. Considered separately the reef edge had a live coral cover of 59.6% and the reef flat 26.5%. The abundance of soft corals (alcyonaceans) on the reef flat as compared to other reefs is probably due to their ability to tolerate turbidity and extreme low tides. High species richness, diversity, abundance and large size index at the reef edge indicate that the environment there is more favourable to the hard corals (scleractinians) than the reef flat. Macroalgae are abundant.

INTRODUCTION

Studies on coral reefs in Malaysian waters have been mainly descriptive. These include the study of Purchon (1956) which was limited to a reference collection of corals occurring around Singapore. Chuang (1961) also made a collection around Singapore and extended it with some collections in Malaysian seas (Chuang, 1973). Work by Scheer (1970) on the second Xarifa Expedition in 1958 briefly surveyed the area from Penang to the Sembilan Islands, approximately 80 nautical miles to the south in the Straits of Malacca. A description of the species found, together with ecological notes of the collection sites, is given by Pillai and Scheer (1974). This paper presents a description of the community structure in terms of species composition, zonation and diversity patterns of the fringing reef community at Cape Rachado.

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METHODS

At Cape Rachado (Fig. 1) the fringing reef extends as a reef flat almost all the way round the cape. The reef flat where this study was carried out extends from the rocky shore in a westerly direction for a distance of over 85 metres to the reef edge (Fig. 1).

The reef was first surveyed for a reference collection of corals. Hard corals were identified following Searle (1956), while soft corals were identified by Dr. J. Verseveldt (The Netherlands). The method employed for quantitative sampling of the coral distribution is the contiguous transect technique (Maragos 1974). A transect was marked by large nails hammered into coral heads at various intervals. A one metre quadrat, subdivided into a grid of 100 squares of equal size was used in sampling all along one side of a transect line (beginning with quadrat 1 located near the rocks and ending with quadrat 87 at the reef edge). A sketch of the coral colonies in each quadrat was drawn to scale on a data sheet. Any colony growing independently of its neighbour was considered an individual colony, i.e. whenever an empty space was recorded between two adjacent colonies (Loya 1972). Growth forms were noted. For growth forms more inclined to flat horizontal growth such as the laminated *Astraeopora myriophthalma*, the percentage cover was derived directly from the number of squares occupied within the quadrat. For growth forms such as those of the massive *Goniastrea retiformis* where encrusting corallites are found on the vertical face of the boulders, the depth was measured and recorded on the sketch and used to calculate the surface area. This is a better assessment of coral cover than a two dimensional accounting that was applied to the flat form. The cover of various species of macroalgae within the quadrat was also recorded. The study was carried out from April to September 1976.

RESULTS

Environmental parameters

Tidal exposure of the reef flat (calculated for August and September 1976 based on tidal data obtained from the Tide Tables) show that the reef flat was exposed 6% of the time for the above period. At extreme low spring tides the reef flat may be exposed to the air for more than 3 hours. The reef flat extends from the rocky shore for about 50 metres where it slopes gently again for a distance of 10 metres before reaching the reef edge where numerous surge channels are present (Fig. 2). These channels are trenches which are in continuity with the open sea. The reef edge extends for about 17 metres and then falls off gently to a flat muddy bottom. Corals grow on the reef slope up to a depth of 8 metres.

Turbidity readings determined at the reef edge were variable ranging from Secchi disc readings of 2 m on an overcast day with rough sea when water had a high sediment load to readings of 7 m on a clear day with calm sea and a lower sediment load.

Coral fauna

The list of the corals found in Cape Rachado with their relative abundance and morphological forms are presented in Table 1. At least 41 species were present which includes 35 scleractinian hermatypes, one milliporinid and 5 alcyonaceans. Only one genus of solitary coral, *Fungia*, was found.

The abundance, frequency and size index of coral species found on the transect are included in Table 1. Abundance refers to the percentage cover of the species with respect to the total area of the transect. The frequency of a species is the number of quadrats in which the species is present. Of the 87 quadrats in the transect, only three did not contain any coral. These quadrats had sandy substrates. Size index was calculated for individual species and quadrats. The data from the former allows comparison of colony size between species, while the latter, between quadrats. Size index for species is derived from the division of total cover of the species (for the whole transect) by the number of its colonies. This is a measure of the average size of the coral species (Table 1). Size index for quadrats is derived from the division of percentage cover in one quadrat by the number of colonies found in it (Fig. 3).

Species richness i.e. the number of species per unit area was also calculated. This was computed for quadrat sizes of 1 m², 2 m², 5 m² and 10 m² (Fig. 4). Species richness is a measure of diversity which takes into account the number of species without considering the relative proportion of each species. To include the latter parameter in the calculation, the Shannon-Weaver (1949) index was computed using

$$H_c' = - \sum P_i \ln P_i$$

where P_i is the proportion (percent cover) of the 'ith' species in a sample and \ln refers to the natural logarithm. This index was computed for contiguous quadrats of five and is presented together with coral abundance in Fig. 5. Abundance here refers to the percentage cover of corals in the quadrats irrespective of the species composition in the quadrats.

To measure dominance of one or few species in a quadrat, the Evenness Index (Pielou, 1966) was used. This is the ratio of the observed Shannon-Weaver diversity index, H_c' , to the maximum diversity index H_{\max}' . The diversity index is maximal when the proportion of all species in a sample is equal. When one or few species is much more abundant than the rest, the Evenness index is low (Fig. 6). Numerical abundance of corals measures distribution of coral colonies without regard to number of species and proportion of each species (Fig. 7). For a zonation model of the reef, the coral cover of 15 contiguous quadrats are pooled together (Fig. 8). The zones are named after the dominant species.

Table 1. Abundance in terms of % cover, relative abundance, frequency and size index of corals found in Cape Rachado.

Relative abundance (percentage cover) of species on the transect are based on the following scale of quantification: Abundant (A) = 2%, Common (C) = 1 - 2%, Occasional (O) = 0.3 - 1% and Rare (R) = 0.3%. Corals not found on the transect are listed last (asterisks). Key for growth forms: B = branching; F = foliaceous; G = globular; L = laminate; M= massive.

Species	Growth forms	Abundance (% cover)	Relative abundance	Frequency (No. of quadrats)	Size Index
All corals	-	32.94	-	84	-
<i>Lobophytum crassum</i> Von Marenzeller	B	0.83	O	8	1.95
<i>Lobophytum crassospiculatum</i> Moser	B	1.49	C	5	1.71
<i>Lobophytum pauciflorum</i> (Ehrenberg)	B	1.06	C	4	3.85
<i>Sarcophyton ehrenbergi</i> Von Marenzeller	M	2.28	A	7	9.45
<i>Astraeopora myriophthalma</i> (Lamarck)	L	2.00	A	16	5.24
<i>Montipora informis</i> Bernard	L	0.87	O	12	5.03
<i>Pavona frondifera</i> Lamarck	F	1.33	C	17	2.89
<i>Pavona crassa</i> (Dana)	F	0.14	O	1	12.00
<i>Pachyseris speciosa</i> (Dana)	L	0.11	O	1	10.00
<i>Fungia fungites</i> (Linnaeus)	L	0.02	O	2	2.00
<i>Gonipora lobata</i> Milne-Edwards & Haime	G	0.03	O	2	0.75
<i>Porites convexa</i> Verrill	F	2.15	A	17	6.68
<i>Porites nigrescens</i> Dana	B	0.17	O	1	14.50
<i>Porites lutea</i> Milne-Edwards & Haime	M	7.39	A	34	13.40

Species	Growth forms	Abundance (% cover)	Relative abundance	Frequency (No. of quadrats)	Size Index
<i>Porites eridana</i> Umbgrove	B	0.41	0	9	2.57
<i>Favia speciosa</i> (Dana)	G	0.82	0	23	1.99
<i>Favites abdita</i> (Ellis & Solander)	M	1.71	C	24	2.29
<i>Goniastrea pectinata</i> (Ehrenberg)	M	2.05	A	23	3.97
<i>Goniastrea retiformis</i> (Lamarck)	M	2.50	A	26	3.95
<i>Goniastrea benhami</i> Vaughan	M	3.38	A	30	6.39
<i>Platygyra lamellina</i> (Ehrenberg)	M	0.22	R	3	4.88
<i>Merulina ampliata</i> (Ellis & Solander)	L	1.52	C	9	6.97
<i>Galaxea fasciculatis</i> (Linnaeus)	G	0.32	0	5	4.67
<i>Lobophyllia hemprichii</i> (Ehrenberg)	M	0.13	0	2	5.50
* <i>Millepora platyphylla</i> Hemprich & Ehrenberg	L				
* <i>Sinularia leptoclados</i> (Ehrenberg)	B				
* <i>Psammocora</i> <i>togianensis</i> Umbgrove	G				
* <i>Psammocora contigua</i> (Esper)	F				
* <i>Pocillopora verrucosa</i> (Ellis & Solander)	B				
* <i>Montivora solanderi</i> Bernard	L				
* <i>Montipora laevis</i> Quelch	B				
* <i>Acropora concinna</i> (Brook)	B				

Species	Growth forms	Abundance (% cover)	Relative abundance	Frequency (No. of quadrats)	Size Index
* <i>Acropora tubicinaria</i> (Dana)	B				
* <i>Podabacia crustacea</i> (Pallas)	L				
* <i>Goniopora malaccensis</i> Brueggemann	G				
* <i>Alveopora excelsa</i> Verill	F				
* <i>Hydnophora rigida</i> (Dana)	G				
* <i>Cyphastrea chalcidicum</i> (Forskaal)	G				
* <i>Mycedium tubifex</i> (Dana)	L				
* <i>Pectinia lactuca</i> (Pallas)	F				
* <i>Turbinaria peltata</i> (Esper)	L				

Macroalgae associated with corals

Both living and dead coral skeleton provide a habitat and substrate for algae and a variety of sessile and burrowing organisms. A conspicuous feature of the Cape Rachado coral reef is the abundance of macroalgae. The brown algae predominate represented by *Sargassum* sp., *Padina commersonii* and *Turbinaria* sp. Another abundant species is the red coralline algae, *Corallina* sp. The above four species were quantitatively surveyed along 70 metres of the transect (Table 2). *Padina* forms small individual bunches of pale brown, fan shape fronds with concentric rings, but cover only little space. *Turbinaria* occurs in clumps near the reef edge. *Corallina*, with biramous branching resulting in thick bushy growth occupies little space, thus its distribution, is patchy and occupied only a few squares (Table 2).

Table 2: Distribution and abundance of macroalgae on the transect.

Numbers represent the number of 10 cm squares occupied by the algae in each one metre quadrat.

SPECIES					SPECIES					SPECIES				
Quadrat Number	<i>Sargassum</i> sp.	<i>Padina commersonii</i>	<i>Turbinaria</i> sp.	<i>Corallina</i> sp.	Quadrat Number	<i>Sargassum</i> sp.	<i>Padina commersonii</i>	<i>Turbinaria</i> sp.	<i>Corallina</i> sp.	Quadrat number	<i>Sargassum</i> sp.	<i>Padina commersonii</i>	<i>Turbinaria</i> sp.	<i>Corallina</i> sp.
1	-	-	-	-	25	38	-	-	2	49	95	3	6	-
2	-	-	-	-	26	40	-	2	-	50	100	5	8	-
3	-	-	-	-	27	30	-	1	-	51	95	2	2	1
4	2	-	-	-	28	30	-	3	-	52	100	-	-	-
5	3	-	-	-	29	30	20	-	1	53	95	-	-	3
6	15	3	-	-	30	5	-	-	1	54	80	-	4	-
7	60	-	-	-	31	10	5	-	-	55	100	6	5	-
8	70	-	-	-	32	35	-	4	2	56	97	3	5	-
9	80	-	1	-	33	46	6	-	-	57	96	3	13	8
10	85	-	-	-	34	70	5	6	2	58	98	-	-	-
11	85	4	-	-	35	10	5	-	-	59	98	-	-	2
12	15	-	3	-	36	10	4	-	2	60	100	-	-	-
13	15	4	-	-	37	50	10	-	-	61	94	-	5	-
14	10	5	-	-	38	5	5	3	-	62	96	-	3	3
15	18	-	-	-	39	15	10	-	3	63	99	5	12	-
16	7	-	5	-	40	40	8	-	-	64	98	2	5	2
17	70	-	-	-	41	50	9	-	1	65	90	-	5	2
18	60	-	-	-	42	70	10	2	-	66	87	-	8	2
19	45	-	7	-	43	85	5	1	-	67	80	2	15	3
20	35	-	-	-	44	90	4	-	4	68	50	-	-	-
21	35	-	6	-	45	95	3	4	-	69	46	-	-	-
22	78	-	-	-	46	85	-	-	5	70	20	-	25	-
23	52	9	-	-	47	-	-	-	-					
24	78	-	2	-	48	100	5	4	2					

DISCUSSION AND CONCLUSIONS

Fifty six percent of coral species found in Cape Rachado were present on the 1 x 87 metre belt transect studied. Live coral cover on the reef was low (32.9%). However, if considered separately the reef edge comprising 17 metres of the transect has a coral cover of 59.6% and the reef flat of 70 metres only 26.5%. The high coral cover at the reef edge compares favourably with the reef slope at Fanning Island, Line Islands, where Maragos (1974) obtained a value of 60%.

Size indices along the transect (beginning from quadrat 1 at rocky shore to quadrat 87 at reef edge) show extreme variability (Fig. 3), ranging from 1% to 95%. However, the two regions from quadrat 25 to 35 and 46 to 64, show significantly lower size index than the adjacent regions. The former corresponds to areas dominated by *Goniastrea retiformis* and *Lobophytum* spp. The latter an area dominated by *Astraeopora myriophthalma*, *Pavona frondifera* and *Porites eridani*. These two regions also show low abundance (Fig. 5) but the number of colonies between them differ greatly (Fig. 7).

The opposite ends of the transect between quadrats 5-15 (*P. lutea* zone) and quadrats 70-87 (mixed zone) show significantly higher abundance (Fig. 5). The first area (on the reef flat), exclusively colonized by *P. lutea* also showed low diversity, species richness, evenness index and frequency but large size index. Individual colonies of the species are spread over large areas, thereby excluding other species. This reduces the diversity, species richness and frequency. On the other hand, the second area is a zone equally dominated by a number of species such as *Sarcophyton ehrenbergi*, *Porites convexa*, *Merulina ampliata* and *Goniastrea* spp. (Fig. 8). Here the zone is characterised by high diversity, species richness, evenness index and frequency and also a large size index.

Generally the first and second areas reflect the characteristic coral species of the reef flat and reef edge respectively. This difference in coral species characters is a result of contrasting environmental conditions. The reef flat is subject to stress of high temperature and variable salinity. Exposure to the sun during periods of low spring tides increases the temperature considerably and subject the corals to severe desiccation. Loya (1976) reported mass mortality of corals in the Gulf of Eilat during a period of extreme low tides in 1970. In the event of rain during periods of tidal exposure, the salinity may be reduced. Regular occurrence of such fluctuations causes mortality of less hardy and competitive species; thereby reducing the diversity. Species which can tolerate such environmental conditions dominate the substrate.

Another possible factor for the difference between the reef flat and reef edge is the presence of surge channels in the latter. These surge channels probably bring in a good supply of oxygen and food. Further, the extra vertical dimension of the reef edge increases the area of substrate for the settling of planulae. This phenomenon

of high abundance and diversity on the reef edge is equivalent to the 'edge effect' reported by Porter (1972).

Astraeopora myriophthalma and *Porites eridani* are the dominant corals of the region between quadrats 50 to 60, a zone that is in the trough of the reef flat. It is also a zone that shows low species richness, abundance, frequency and diversity indices. Individual colonies of *Astraeopora myriophthalma* are spread over large areas in this zone as shown by its relatively high size index and hence it has reduced the diversity by physical exclusion of other corals. The environment here is less severe as it is not subject to tidal exposure.

The seaward end of the reef flat (between quadrats 60 and 70) is covered mostly by *Porites convexa* and *Sarcophyton ehrenbergi*. *Porites convexa* is only found seaward from this region onwards which in view of its proximity with the reef edge, benefit from the food and oxygen brought in by the surge channels. Maragos (1974) described the *Sarcophyton* sp. as a soft coral characterised by a continuous spongy "corallum" that seemingly smothers other corals by growing over them. This alcyonacean may be capable of rapid growth and this may help in achieving local dominance.

Analysis of the size index of quadrats (Fig. 3) indicates that the smallest colonies existed in the middle region of the reef flat (quadrats 15 to 65) and the largest colonies occurred at both the seaward and landward ends of the reef flat. These data support the hypothesis that large colonies of *Porites lutea* and *Sarcophyton ehrenbergi* may physically exclude other corals.

Turbidity which is correlated to sediment load is very high in Cape Rachado. Visibility was limited. Compared to visibility of Fanning Island which is 50 m in terms of Secchi disc readings (Maragos 1974), the water here is indeed very turbid. Sediments which settle on the reef flat smother the corals. This leads to a significantly lower living coverage and diversity, a conclusion that is also shared by Loya (1972) concerning the Eilat coral reef flat.

Soft corals (alcyonaceans) which do not contribute to the reef skeletal framework are abundant in Cape Rachado contributing 17% of total coral cover on the transect. This is in contrast to the situation in most reefs, e.g. the Great Barrier Reef where the soft corals are negligible. Soft coral abundance in the Red Sea is due to their ability to tolerate turbidity and occasional extreme low tides better than stony corals which are more adapted to strong currents and swells (Schuhmacher 1975).

It is apparent that the abundance of soft corals in Cape Rachado is also a consequence of the same abiotic factors. The ability of soft corals to survive in turbid conditions may be due to their structural flexibility which allows them to dislodge any sediments settling on them. During extreme low tides, the soft corals droop over the substrate, reducing the exposure of polyps to direct sunlight.

They are also able to retain water in their structures which acts as a coolant to the heat from solar radiation. All these coupled with mucus secretions enable the soft corals to overcome desiccation.

Loya (1972) suggested that the best strategy for scleractinian corals trying to grow in areas of high sedimentation is to develop some kind of cleaning mechanism or evolve a special growth form which avoids sediment accumulation. Three out of the four most abundant species in the high sedimentation rate areas, on the coral reef in Eilat were branching corals. Roy and Smith (1971) working on Fanning Lagoon, Line Islands, also showed that ramose (branching) forms dominate the turbid water rather than the massive forms. In contrast, the most abundant species in Cape Rachado are corals with massive forms such as *Porites lutea* and the faviid species such as *Favia speciosa*, *Favites abdita*, *Goniastrea retiformis*, *G. pectinata*, *G. benhami* and *Platygyra lamellina*. These corals probably have a cleaning mechanism to remove sediments through mucus secretions or ciliary action. Large specimens of the massive faviid corals often have a dead top indicating that polyps exposed directly to sedimentation are unable to cope with the problem. It is the polyps encrusted on the vertical plane of the boulders which are able to survive as sediments do not settle there. *Porites lutea* shows essentially the same trend but large specimens have been found with short stunted projections which have less horizontal surfaces where sediments can settle. This development by *Porites lutea* towards branching or ramose forms is an adaptation to the stress of high sedimentation.

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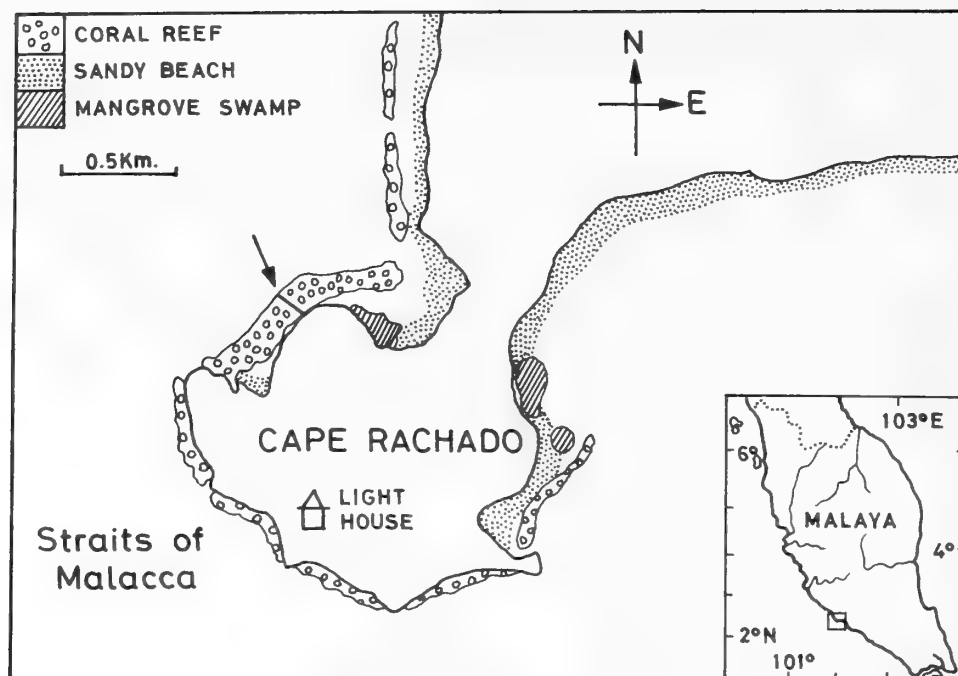


Fig. 1 Cape Rachado and surrounding coral reefs. Study transect indicated by arrow

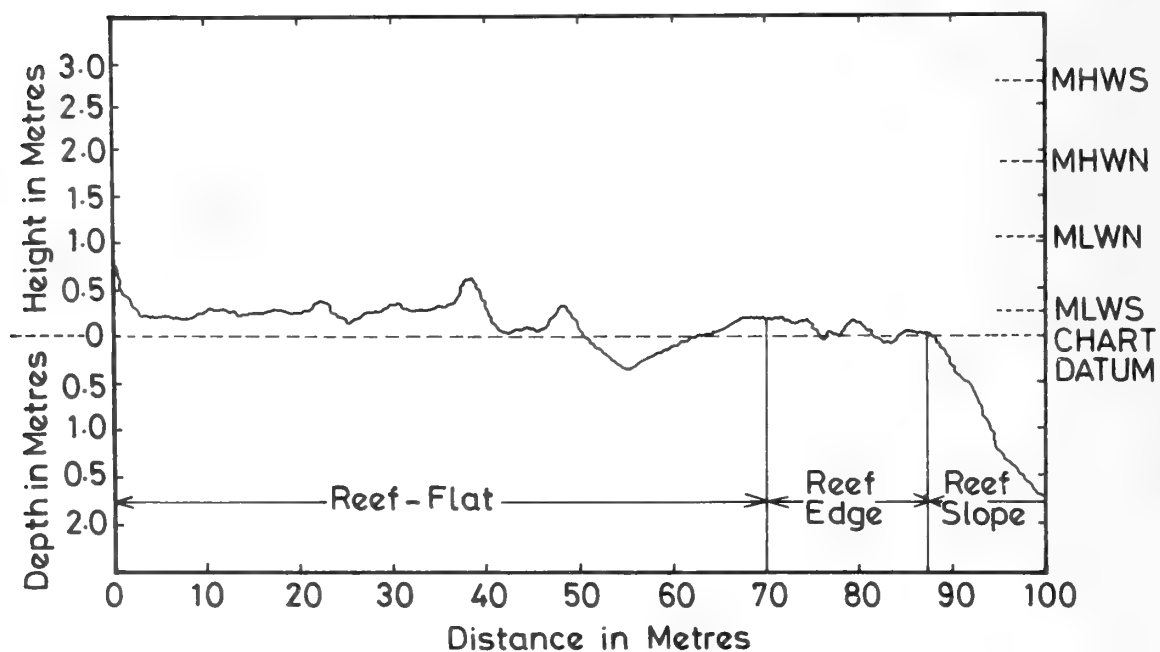


Fig. 2 Bathymetry of reef transect in relation to the various tidal levels

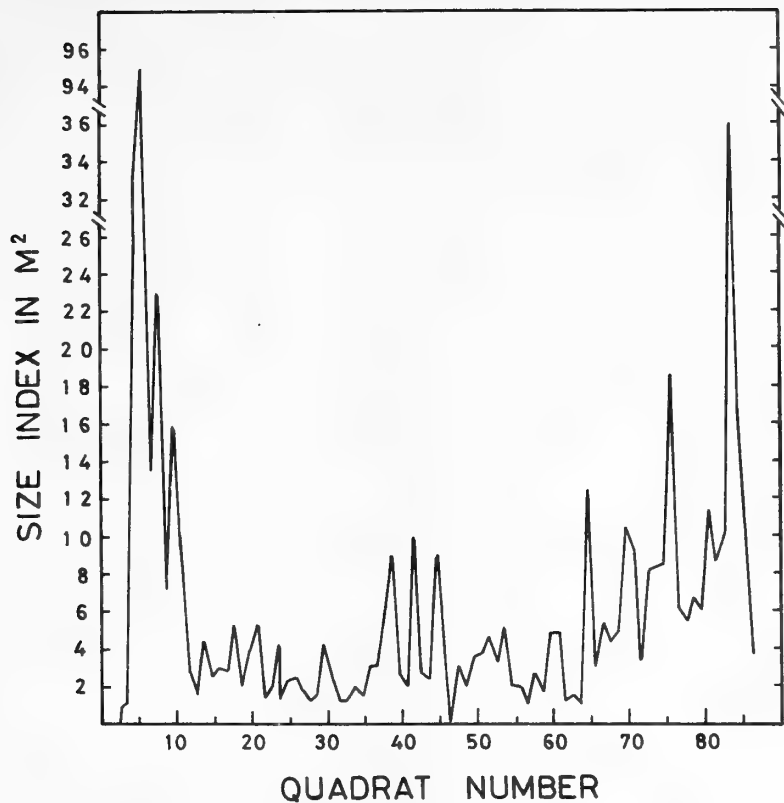


Fig. 3 Size index for quadrats (an estimate of average colony area) plotted as a function of transect location

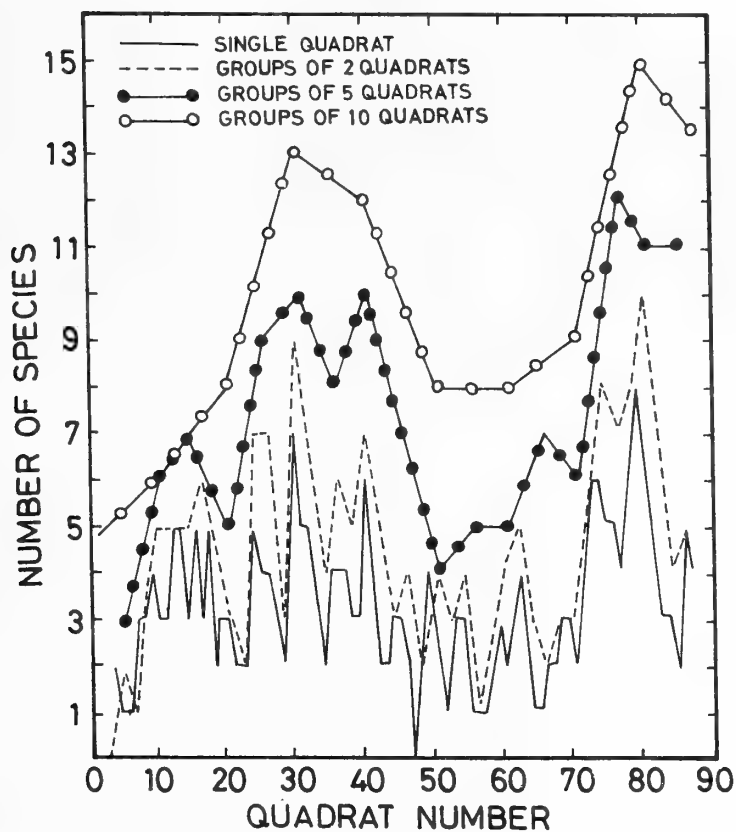


Fig. 4 Species richness plotted as function of transect location for single quadrats, for groups of 2, 5 and 10 quadrats

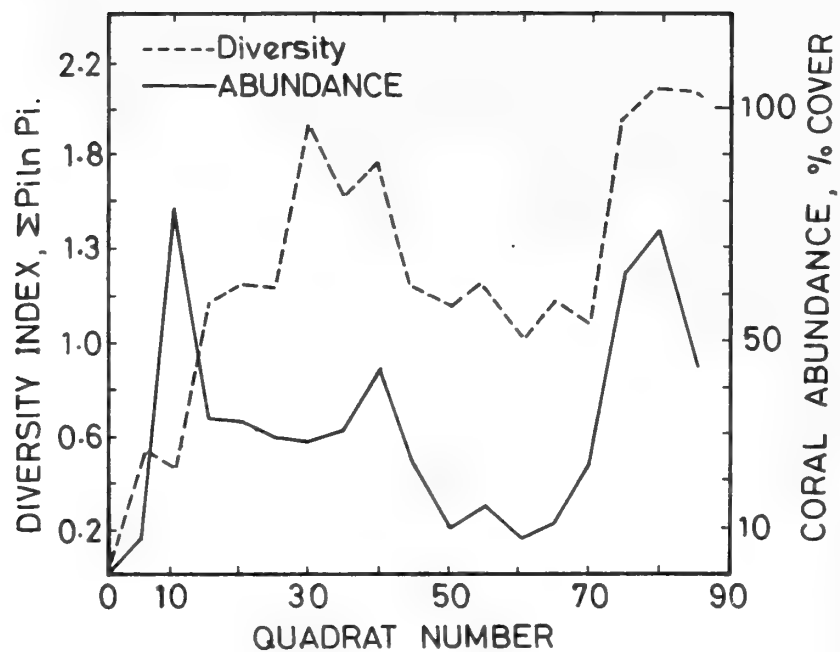


Fig. 5 Coral abundance and the Shannon-Weaver diversity index plotted as a function of transect location with values based on pooling of contiguous groups of five quadrats

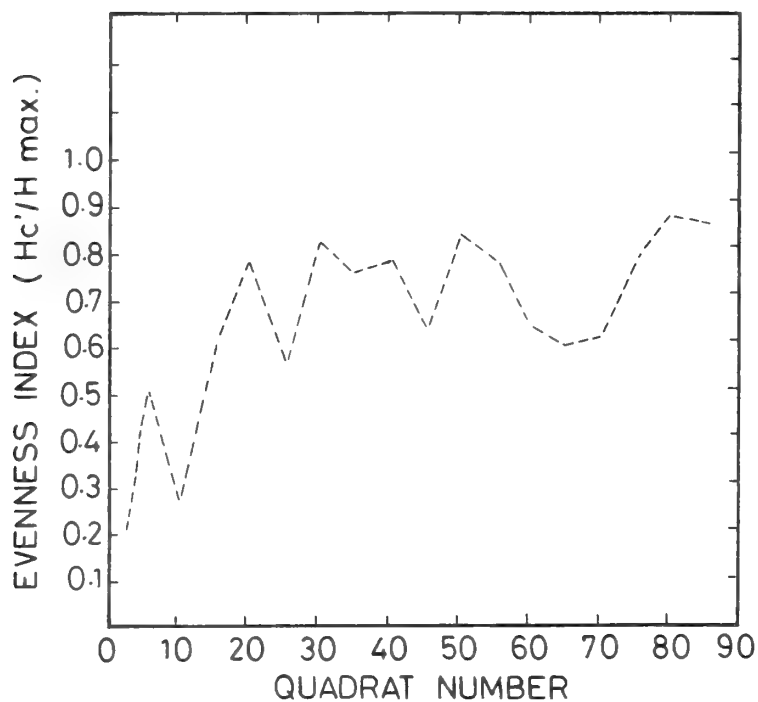


Fig. 6 Evenness Index (H_c'/H_{max}) plotted as a function of transect location for groups of five quadrats

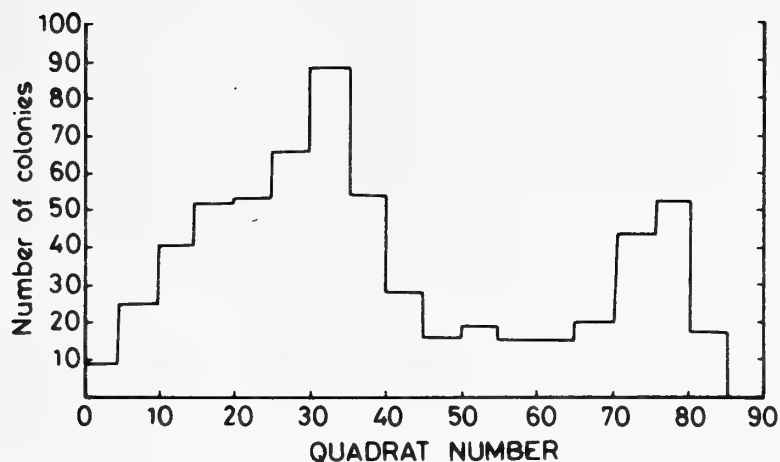


Fig. 7 Number of quadrats at 5 meter intervals along transect

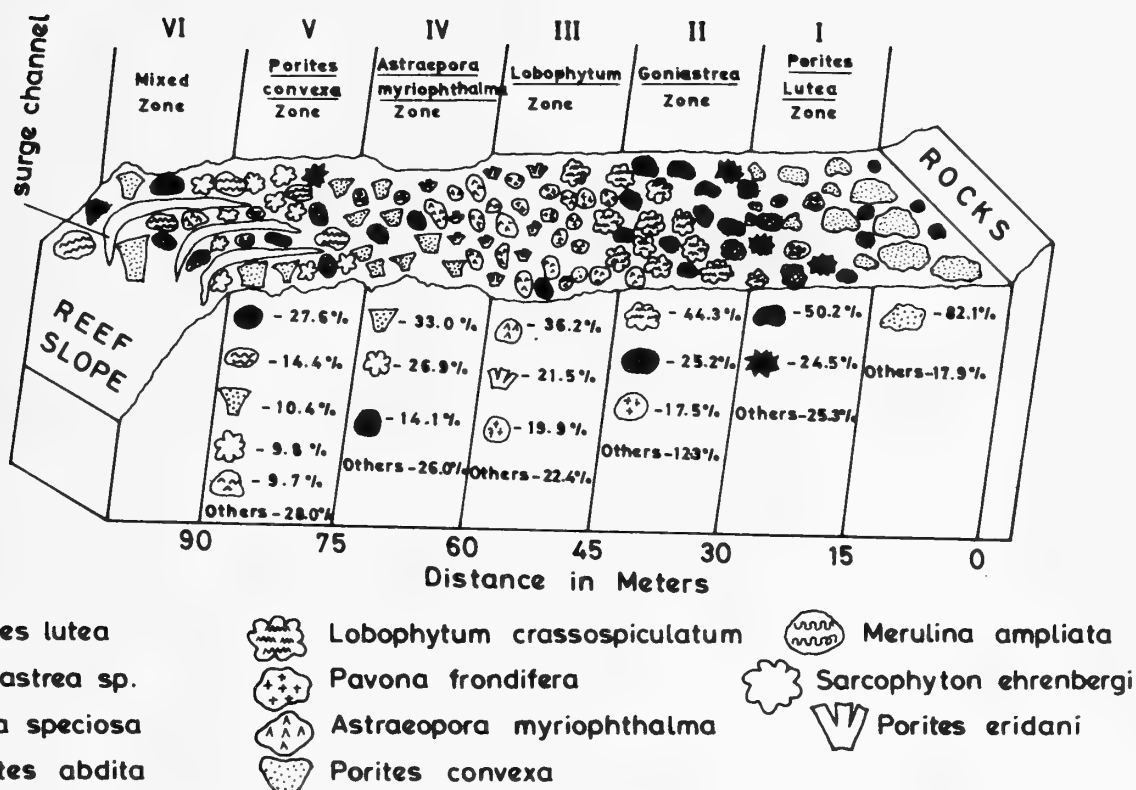


Fig. 8 Zonation model of coral reef transect at Cape Rachado

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PONTONIINE SHRIMPS OF HERON ISLAND

by A. J. Bruce

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PONTONIINE SHRIMPS OF HERON ISLAND

by A. J. Bruce¹

Heron Island, in the Capricorn Island group, is a small coral cay, situated at 23°26.6'S., 151°54.8'E., near the southern end of the Great Barrier Reef system, approximately 40 nautical miles from the mainland at Cape Capricorn and 38 from Bustard Head. The island is surrounded by an extensive reef flat, of about 27 km², with a central lagoon, and the adjacent Wistari Reef, of about 25 km², lies to the southwest and is separated only by a narrow channel. The general features of these reefs have been described by Flood (1971) and Flood and Jell (1978), and the faunistic background by Mather and Bennett (1978).

The crustacean fauna of the Great Barrier Reef in general, and Heron Island in particular, have been little studied. The report on the decapod crustaceans collected by the Great Barrier Reef Expedition (1928-29) included reference to only 30 species of Caridea, of which only 8 belonged to the subfamily Pontoniinae. Scattered references to isolated species have also occurred but much of the crustacean fauna must still be considered as largely unknown. A study of the decapods associated with branching corals by Patton (1966) provided several new records to the Australian fauna, as well as important biological information, but little work has been subsequently published.

The caridean fauna of coral reefs presents a considerable variety of species, that are dominated by the members of three taxa, the Pontoniinae, the Alpheidae and the Hippolytidae. Although the shrimps are often abundant, they are frequently of small size and cryptic habits, so that they are rarely seen by casual observation. Many have adopted a "commensal" way of life, and are even less amenable to direct observation. This report deals only with the subfamily Pontoniinae, of which the vast majority of species lead commensal lives. The abundance and variety of potential hosts in the coral reef biotope is illustrated by the parallel abundance of these commensal shrimps, which exhibit a wide range of morphological adaptations to their particular niches and also often show a high degree of host specificity

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in their associations. The present study, of the fauna of a greatly restricted area provides a good illustration of the abundance and diversity of crustacean life present at the southern end of the Great Barrier Reef.

SYSTEMATIC ACCOUNT

Subfamily PONTONIINAE Kingsley, 1878

Allopontonia iaini Bruce

Northern Wistari reef, 80 ft., two specimens (one juvenile) on *Salmacis sphaeroides*, 16 April 1977.

The specimens agree closely with the colour pattern reported in the original description.

The species has not been previously reported from Australian waters, and the association represents a new host record. Previously known only from the type locality, Zanzibar, and Wasin Island, Kenya.

Anchistioides compressus Paulson

Wistari reef, slope, 15 ft., one specimen, from unidentified sponge, 23 May 1977.

This species has not been previously recorded from Australian waters. It is known to associate with sponges of the genera *Haliclona* and *Caminus*.

The type locality is the Red Sea and the species is also known from East Africa, the Andaman Islands, Japan and the Tuamotu Islands.

Anchistioides willeyi (Borradaile)

Heron Island, southern reef slope, 36 ft., two specimens from unidentified sponge, 20 April 1978. Northern reef slope, 38 ft., one specimen, from an unidentified sponge, 9 May 1978. Wistari reef, slope, 30 ft., three specimens, from unidentified sponge, 6 April 1979.

This species has been previously reported from One Tree Island in the Capricorn group. It is also known from Zanzibar, Kenya, Madagascar, the Maldive Islands, Indonesia and the type locality, New Britain.

Anchistus custoides Bruce

Heron Island, south western reef, at base of slope, 20 ft., one pair of specimens from *Atrina vexillum* (Born), 21 July 1976, and a

second pair from the same host at 10 ft., 16 August 1976, from the central lagoon.

Previously known only from the type locality, Gillett Cay, Swains Reefs; One Tree Island, Capricorn group, and from Palau, Caroline Islands.

Anchistus demani Kemp

Heron Island, southern reef flat, 1 ovigerous ♀, from *Tridacna* sp. 11 December 1968.

Previously recorded from One Tree Island, Capricorn group and otherwise known from the type locality in the Andaman Islands, Zanzibar, Kenya, Madagascar, the Comoro and Seychelle Islands, and from the Marshall Islands.

Apopontonia falcistrostris Bruce

Heron Island, north western reef slope, 30 ft., 1 ovigerous ♀ in *Psammascus* sp., 26 April 1979, coll. J.P. Halversen.

The single example agrees very closely with the description of the holotype from north eastern Madagascar, at a depth of 210 ft. The host of this species has not been previously identified, and the present record is only the second known occurrence. The species is new to the Australian fauna.

Conchodytes meleagrinae Peters

Common in pairs in specimens of the black-lipped pearl oyster, *Pinctada margaritifera*, which are numerous on the reef flats.

First recorded from the Torres Straits in Australian waters (Bate, 1888) and subsequently from Bathurst Island, the Low Isles, Swains Reefs, and from One Tree Island in the Capricorn group. Its distribution extends throughout the Indo-West Pacific, from the northern Red Sea to Hawaii, but there are no records from south eastern Polynesia. Most reports are in association with *Pinctada margaritifera* L.

Conchodytes tridacnae Peters

Heron Island, north western reef flat, low water, 1 male, one ovigerous ♀, in *Tridacna maxima* L., 1 May 1979.

Rarely collected, but probably not uncommon in *Tridacna* spp. McNeill (1926) recorded this species from Northwest Island, Capricorn group, but did not identify the host. It is most probably from *Tridacna* sp. rather than *Pinna*, as the latter are uncommon or absent from these islands. The specimens reported upon by Miers (1884) from Warrior Reef, Torres Straits, also belong to this species, but the

specimen from Keppel Island is no longer identifiable. All are in the collection of the British Museum (Nat. Hist.).

The range of this species extends from East Africa to the Marshall Islands.

Coralliocaris graminea (Dana)

Abundant in corals of the genus *Acropora*, on Heron Island and Wistari reefs. This species was first reported from Heron Island by Patton (1966) and has also been recorded from the Low Isles (McNeill, 1968). It has been found in association with *Acropora corymbosa*, *A. cymbicyathus*, *A. diversa*, *A. hebes*, *A. squamosa* and *A. variabilis*.

The distribution of the species appears to extend throughout the Indo-West Pacific region, but the exact identity of some of the records concerned need verification due to confusion with *C. viridis*, (see below).

Coralliocaris superba (Dana)

An abundant associate of corals of the genus *Acropora* on the reef flat, lagoon bommies and the reef slope. First recorded from Heron Island by Patton (1966), it has been found in association with *A. diversa*, *A. pulchra*, *A. cymbicyathus* and *A. digitifera*.

Also recorded from Swain's Reefs, its range extends from the Red Sea to the Society Islands, but does not include Hawaii.

Coralliocaris venusta Kemp

Numerous examples of this species have been collected from corals of the genus *Acropora*, from the reef flat down to a depth of 60 ft. The hosts include *A. hyacinthus*. *C. venusta* exists in two colour forms, both of which occur on Heron Island.

Previously recorded from Heron Island by Patton (1966), who studied additional specimens from Willis Island and Restoration Rock, and from One Tree Island (Bruce, 1977a). Otherwise recorded from the Red Sea to the Ryukyu and Samoan Islands.

Coralliocaris viridis Bruce

Heron Island, outer reef flat, 1 ft., three specimens from *Acropora* sp., 16 April 1979. - Lagoon, 3 ft., in *Acropora* sp., one male, one ovigerous ♀, 21 October 1976. - Reef flat, 1 ft., 1 ovigerous ♀, in *Acropora* sp., 6 April 1978.

Apparently uncommon on Heron Island, *Acropora* species, where *C.*

graminea is dominant. This species has been previously reported from One Tree Island (Bruce, 1977a) but its exact distribution is obscure due to confusion of earlier records with *C. graminea*. The type locality is Mombasa, Kenya, and it is also known from the Isle Europa, the Maldiv Islands, Ceylon and the Ryukyu Islands.

Dasella herdmaniae (Lebour)

Heron Island, north west reef slope, 50 ft., 1 specimen in unidentified ascidian, 5 June 1979.

Not previously recorded from Australian waters and known only from the type material from Madras, south India. Previously recorded from the ascidian *Herdmania momus* (Savigny) where it was found in association with the alpheid shrimp *Synalpheus herdmaniae*.

Dasycaris ceratops Holthuis

Wistari Reef, northern side, at bottom of slope, 80 ft., 1 ovigerous ♀, on *Pteroides bankanense* Bleeker, 16 April 1977.

This species has also been reported from Lodestone Reef, Queensland, and further from Borneo Bank and Zanzibar. This host constitutes a new record.

Hamodactylus agabai Bruce

Heron Island, channel reef slope, 36 ft., on *Nephthyea* sp., 1 ovigerous ♀, 20 April 1978; idem, in *Nephthyea* sp., 2 juveniles, 20 April 1978; south east reef slope, 20 ft., 1 specimen on alcyonarian, 10 May 1978. Wistari Reef, north west slope, 15-20 ft., on *Nephthyea* sp., 2 ovigerous ♀, 18 May 1979.

Not previously recorded from Australian waters and known only from the northern Red Sea, where the types were found, also in association with alcyonarians, on *Lithophyton* sp.

Hamodactylus broschmai Holthuis

Heron Island, reef slope, 50 ft., 1 juvenile on *Subergorgia reticulata*, 20 September 1976; 90 ft., one specimen on gorgonian, 28 November 1976; 20 ft., 12 specimens (with 5 ovigerous ♀), on *Melitheia ocracea*, 18 January 1978; 60 ft., 4 specimens (2 ovigerous ♀), on gorgonian, 29 March 1978.

This species has not been previously recorded from Australian waters, but has been reported from Zanzibar, Kenya, Madagascar, Indonesia and new Caledonia, usually in association with gorgonian hosts. Both associations represent new host records.

Hamodactylus noumeae Bruce

Heron Island, 35 ft., 4 specimens (1 ovigerous ♀) on *Euplexora flava*, 26 July 1976; 50 ft., 1 juvenile, on *Subergorgia reticulata*, 20 September 1976; 90 ft., 1 ovigerous ♀, gorgonian indet., 28 November 1976. Wistari Reef, 40 ft., 1 ovigerous ♀ on *Pseudopteragorgia pinnata*, 15 September 1976; 85 ft., 1 ovigerous ♀, on gorgonian indet., 20 November 1978.

This species is new to the Australian fauna and the hosts all represent new association records. Known only from East Africa, Indonesia and New Caledonia.

Hamopontonia corallicola Bruce

Heron Island, reef flat, 1 male on *Goniopora*, 23 October 1976; 8-10 ft., 3 specimens on *Fungia actiniformis*, 27 October 1976; reef 2 ovigerous ♀ on *Goniopora* sp., 25 July 1977. Wistari Reef, north east end, 40 ft., 1 ovigerous ♀ on unidentified anemone, 10 April 1978; north east reef, 25 ft., 4 specimens on *Goniopora* sp., 8 May 1979.

Not previously recorded from Heron Island but reported from Peloris Island, Queensland (Bruce, 1977). Otherwise known only from the type locality, Hong Kong and southern Japan.

Harpiliopsis beaupresii (Audouin)

Abundant on corals of the genera *Stylophora* and *Pocillopora* on Heron Island and Wistari reefs. The commonest pontonine shrimp found in association with these corals in this locality.

First recorded from Heron Island by Patton (1966) this species occurs throughout the Indo-West Pacific region, from the Red Sea to Hawaii, and Easter Island, although there appear to be no records from the greater part of the South Pacific islands east of the Marshall Islands.

Harpiliopsis depressa (Stimpson)

Comparatively uncommon at Heron Island in comparison with *H. beaupresi*, but occurring in the same host corals.

First recorded from Heron Island by Patton (1966) and also known from the Diamond Islets (Bruce, 1977a). Widespread throughout the Indo-West Pacific region from the Red Sea to Hawaii, and extending to the Galapagos Islands, California, Mexico, Costa Rica, Panama and Columbia in the Eastern Pacific region.

Harpiliopsis spinigera (Ortmann)

Heron Island, north western reef slope, 45 ft., 4 specimens (1 ovigerous ♀) on *Stylophora pistillata*, 5 June 1979. Wistari Reef, slope, 50 ft., 1 specimen from *Seriatopora hystrix*, 15 September 1976. Heron Island, north west reef, flat, low water, 1 male, 2 ovigerous ♀ and 1 juvenile, 16 April 1979.

Uncommon on local corals. Not previously recorded from Australian waters. Distribution uncertain through confusion with *H. depressa*, but probably occurring throughout most of the Indo-West Pacific region on *Pocillopora*, *Stylophora* and *Seriatopora* spp. Known from East Africa, Comoro, Seychelle and Maldiv Islands, Andaman Islands, Celebes and the Samoan Islands. Also known from Panama.

Ischnopontonia lophos (Barnard)

Heron Island, eastern reef slope, 50 ft., 1 pair in *Galaxea fascicularis*, 14 June 1979.

This species has been previously recorded from Australia, from Great Palm, Orpheus and Fantôme Islands near Townsville (Bruce, 1971) and from One Tree Island (Bruce, 1977a), in all cases from *G. fascicularis*.

Jocaste japonica (Ortmann)

Common on corals of the genus *Acropora* on the reef flat and slope, down to a depth of 50 ft.

First recorded from Heron Island by Patton (1966), who reported more specimens from Willis Island and Restoration Rock. Also known from Swains Reefs (Bruce, 1977a).

Known throughout much of the Indo-West Pacific region, excluding the Red Sea, east to the Marshall Islands and New Caledonia.

Jocaste lucina (Nobili)

Abundant in corals of the genus *Acropora*, both on the reef flat and slope, down to a depth of 25 ft.

First recorded from Australia from Heron Island and Wistari Reef, Willis Island, Restoration Rock and Moreton Bay by Patton (1966) and subsequently from Swains' Reefs (Bruce, 1977a). This species has been recorded throughout the Indo-West Pacific region, from the Red Sea to the Society Islands, except for the Hawaiian Islands, where suitable hosts do not occur.

Oncocaris amakusensis Fujino & Miyake

Heron Island, central reef flat, low water, 1 ovigerous ♀, in *Callyspongia* sp., 12 December 1978.

This species has not been formally recorded from Australian waters and is known only from Zanzibar, Hong Kong and Japan and Hawaii.

Oncocaris monodoa Fujino & Miyake

Heron Island, south west reef crest, low water, in encrusting sponge on *Acropora*; 16 November 1977. 1 male, 1 ovigerous ♀ in *Paraesperella*, 10 October 1977.

Previously recorded only from the Amami Islands, Japan. New to the Australian fauna.

Oncocaris oligodentata Fujino & Miyake

Heron Island, southwest reef slope, 1 specimen, 55 ft., in *Spongionella* sp., 2 September 1976.

Not previously recorded from Australian waters and known only from the Amakusa Islands, Japan, and Hong Kong. The association with *Spongionella* represents a new host record.

Palaemonella pottsi (Borrdaile)

Heron Island, reef slope, 40-45 ft., 2 specimens, on crinoid, 10 July 1976; 1 ovigerous ♀, on *Comanthus parvicirrus*, coll. C. Messing, 27 March 1978. Wistari Reef, reef slope, 95 ft., 3 ♂, 2 ovigerous ♀, on three crinoid hosts, 11 October 1976; northern reef slope, 80 ft., 2 specimens on *Comanthina schlegeli*, 6 April 1978; idem, 85 ft., 1 ♂, 1 ovigerous ♀ on crinoid, 18 April 1978; idem, 80 ft., 1 ♂, 1 ovigerous ♀ on crinoid, 7 August 1978; idem, 60-80 ft., 1 ♂, 1 ovigerous ♀, 2 juveniles on *Comanthina schlegeli*, 9 July 1978; idem, 80 ft., 1 ♂, 1 ovigerous ♀ on *Comanthina schlegeli*, 4 July 1978.

Previously recorded in Australian waters from the type locality Mabuaig, Torres Straits (Borradaile, 1915) and also from One Tree Island, (Bruce, 1970, 1977a). Known from East Africa to the Marshall Islands. Commonly found in association with other pontonine and alpheid shrimps on a variety of crinoid hosts.

Palaemonella rotumana Borradaile

Moderately common on the reef flat in and around bases of live corals and in dead coral colonies, but also occurring in similar habitats in deeper water, and has been collected down to a depth of 20

ft. Usually found only in ones and twos.

Previously reported from the Low Islands (as *Periclimenes rotumana*) by McNeill (1968), and from Moreton Bay and One Tree Island, Queensland by Bruce (1970, 1977a). This species occurs extensively throughout the Indo-West Pacific region from the northern Red Sea to Hawaii. It is a free-living micro-predator, and occurs in a wide variety of habitats to a depth of about 400 ft. (70 fm.). Its range also extends into the western Mediterranean Sea, but it has not been found in the Eastern Pacific region as yet.

Palaemonella spinulata Yokoya

Wistari reef, north west slope, 95 ft., under coral, 24 May 1977; north slope, 80 ft., 6 specimens (1 ovigerous ♀), under coral, 19 May 1978; north slope, 80 ft., 2 ovigerous ♀, 3 September, 1978.

Not previously recorded from Australian waters. Probably a free-living micro-predator, like *P. rotumana*, which it closely resembles. Recorded from Japan, Tanganyika and La Reunion only.

Paranchistus pycnodontae Bruce

Heron Island, central lagoon, 10 ft., in *Hyotissa* sp., 1 ♀ (holotype), 17 August 1976, with a specimen of *Onuxodon parvibrachium* (Fowler) [Carapidae].

There have been no subsequent collections of this species from Heron Island or elsewhere. The host was originally identified as *Pycnodonta hyotis* (L.) but is not correctly referable to that species.

Parapontonia nudirostris Bruce

Heron Island, channel, 60 ft., 1 specimen on *Himerometra robustipinna*, 19 October 1976; 1 specimen, 20 ft., 14 October 1977; 1 specimen, 50 ft., on *Himerometra robustipinna*, 30 March, 1978; 1 male, 1 juvenile, 20 ft., 26 April 1978; Wistari reef, 50 ft., 1 male on *Pontiometra andersoni*, 14 July 1978.

Known only from New Caledonia, Heron Island and One Tree Island, Capricorn Islands, and North Stradbroke Island, Queensland.

The above host records represent new host associations. The species has been previously found in association with *Tropiometra afra*.

Paratypton siebenrocki Balss

Patton (1966) reported the occurrence of this species at Heron Island, the first record for Australian waters. The specimen, an

ovigerous ♀, was found in association with the coral *Acropora squamosa* Brook (Bruce, 1969a). There have been no further occurrences.

Paratypton siebenrocki occurs throughout the Indo-West Pacific region from the Red Sea and La Reunion to the Marshall and Samoan Islands.

Periclimenaeus arabicus (Calman)

Heron Island, channel, 95 ft., 1 specimen in sponge, 24 May 1977; central reef flat, 1 male, 1 ovigerous ♀, in sponge, 2 ft., 27 July 1977; reef flat, 1 ovigerous ♀, in sponge, low water, 2 May 1978.

Not previously recorded from Australian waters. Reported from Jibouti and South Arabia; Kenya, Zanzibar and Tanganyika and from Japan. Previously reported in association with sponges of the genera *Callyspongia* and *Acarnus*.

Periclimenaeus ardeae Bruce.

Heron Island, reef flat, low water, 1 ♂, 1 ovigerous ♀ in *Jaspis stellata* (Carter), 2 November 1976; 1 ♂, 2 ovigerous ♀, same host, 26 January 1978.

The type specimens of this species were first described from Heron Island and were from the same sponge (Bruce, 1969). The only other records of this species are from Kenya, in the sponge *Asteropus simplex* (Carter) from a depth of 126-140 ft.

Periclimenaeus bidentatus Bruce

Heron Island, south west reef, 40 ft., 1 ♂ and one ovigerous ♀, in *Arenochalina flamulata* (Lam.), 20 July 1976; patch reef, 55 ft., 1 specimen, in *Spongionella* sp., 2 September 1976.

The type specimens of this species were first described from Heron Island (Bruce, 1969). Specimens have also been reported from Kenya and Zanzibar in *Dysidea fragilis* and *Liosina paradoxa*. The present host associations have not been previously recorded.

Periclimenaeus diplosomatis Bruce

Known only from the type specimens, described from Heron Island, in association with the ascidian *Diplosoma rayneri* MacDonald, collected from the reef flat, 13 December 1978 (Bruce, in press).

Periclimenaeus djiboutensis Bruce

Heron Island, outer reef slope, 36 ft., 1 juvenile in sponge, 20 April 1978; outer slope, 37 ft., 1 ♂, in sponge, 9 May 1978.

Not previously recorded from Australian waters. Known only from Jibuti, Zanzibar and Madagascar. The only previous host record is from *Spongia officinalis* var. *ceylonicus* Dendy.

Periclimenaeus gorgonidarum (Balss)

Heron Island, channel, 60-80 ft., 1 ovigerous ♀ in unidentified sponge, 13 May 1979; Wistari Reef, 80 ft., 1 ♂, 1 ovigerous ♀, in *Siphonochalina* sp., 4 October 1978.

First described from Japan, there have been no subsequent reports of this species from other regions. The Japanese specimens were found in association with *Callyspongia confoederata*. *Periclimenaeus uropodialis* Barnard, from Mocambique and East Africa, is probably synonymous.

Periclimenaeus hecate (Nobili)

Heron Island, reef flat, low water, in tunicate encrusting *Pocillopora* base, 1 ♂, coll. A. Austin, no date, 1976; south east reef slope, 20 ft., 1 ♂, 1 ovigerous ♀ in *Diplosoma* sp., ?*listerianum* (Milne-Edwards), 10 January 1978; north reef slope, 37 ft., 1 ♂, ? tunicate host, 9 May 1978. Wistari Reef, north west reef, 30 ft., 1 juvenile in a colonial tunicate, 26 April 1979.

Previously recorded from Australian waters only from Cape Joubert, Western Australia. Otherwise known from the Gulf of Aden, Kenya, the Comoro and Maldive Islands and Indonesia. Previously found in small encrusting colonies of *Didemnum* in Kenya.

Periclimenaeus odontodactylus Fujino & Miyake

Wistari Reef, north east slope, 35 ft., 1 ♂, 1 ovigerous ♀, in unidentified sponge, 18 June 1979.

This species has not previously been recorded from Australian waters and is known only from Amakusa Island, Japan, where specimens were found in the sponge *Ircinia fasciculata*.

Periclimenaeus ornatus Bruce

Heron Island, reef flat, low water, 1 ♂, 1 ovigerous ♀, in *Jaspis stellifera* (Carter), 2 November 1976; 1 ovigerous ♀, reef flat, low water, same host, 16 January 1977.

First described from specimens collected at Heron Island (Bruce, 1969), this species has since been reported from Zanzibar and Tanganyika. The host sponge has not been previously identified. *P. ornatus* occurs in association with *P. ardeae*.

Periclimenaeus pachydentatus Bruce

Heron Island, north west reef slope, 40 ft., 1 ♂, 1 ovigerous ♀, in *Sigillina deerata* (Sluiter), 27 April 1979.

Previously recorded from the type locality only, in the south east Gulf of Carpentaria, in association with the same host.

Periclimenaeus rhodope (Nobili)

Heron Island, reef flat, low water, 1 ♂, 1 ovigerous ♀, in encrusting sponge on *Acropora*, 26 March 1978.

Not previously recorded from Australian waters. Known only from Jibuti, Somalia, Kenya, Tanganyika and Zanzibar. An associate of sponges of the genus *Haliclona*.

Periclimenaeus tridentatus (Miers)

Heron Island, east reef slope, 25 ft., 1 ♂, 1 ovigerous ♀, in an ascidian, 4 November 1976. Wistari Reef, north west reef slope, 40 ft., 1 ♂, in *Diplosoma* sp., 12 June 1979.

Previously recorded from Australian waters from the type locality, Thursday Island, by Miers (1884). Also known from the Sulu Archipelago and Singapore, with some other dubious records. The host of this species *s. str.* has not been previously recorded.

Periclimenaeus tuamotae Bruce

Heron Island, outer reef slope, 37 ft., 7 specimens, 2 ovigerous ♀, in sponge, 9 May 1978.

Not previously recorded from Australia. Known from Mururoa Atoll, Kenya and Tanganyika. Found in association with *Acarnus ternatus* in Kenyan waters.

Periclimenes affinis (Zehntner)

Wistari Reef, north west slope, 95 ft., on *Comatula cratera* (3), 9 specimens (3 ♂, 4 ovigerous ♀, 2 ♀), 11 October 1976; north reef slope, 80 ft., in *Comanthina schlegeli* (1), 7 specimens (1 ovigerous ♀) 6 April 1978; idem, 85 ft., on crinoid, 13 specimens, 18 April 1978;

idem, 85 ft., on crinoid, 5 specimens, 7 May 1978.

Generally found in association also with *Palaemonella pottsi* and *Periclimenes commensalis*. This species has not been previously found in Australian waters and is known only from New Caledonia, and the northern South China Sea.

Periclimenes amboinensis (De Man)

Wistari Reed, southern reef slope, 75 ft., on *Comantheria briareus*, 1 ♀, 27 January 1978; reef slope, 50 ft., on *Comaster bennetti*, 1 ♂, 1 ovigerous ♀, 14 July 1978.

This species has not been previously recorded from Australian waters and is known only from the original record from Ambon, Moluccan Islands, of which the holotype specimen is no longer extant.

Periclimenes amymone De Man

First recorded from Australian waters at Heron Island by Patton (1966) in corals of the genera *Pocillopora*, *Stylophora* and *Acropora*. Also recorded from One Tree Island, also in the Capricorn group (Bruce, 1971). Known from the Nikobar Islands to the Samoan Islands. Generally common in branching corals at Heron Island.

Periclimenes brevicarpalis (Schenkel)

Relatively uncommon on giant anemones on Heron Island reef flat.

Only two specimens have been collected, on 27 May 1977 and 5 July 1978. Probably more common than these catches indicate but restricted due to absence of suitable hosts such as *Stoichactis* spp.

Known throughout most of the Indo-West Pacific region from the Red Sea to the Line Islands, but not from Hawaii or south eastern Polynesia.

Previously recorded from the Great Barrier Reef by Saville Kent (1893) from Torres Straits, the Low Isles, Cooktown, Port Denison, Magnetic Island and from the Monte Bello Islands.

Periclimenes brocketti Borradaile

Heron Island, reef slope, 1 ovigerous ♀, 2 juveniles on a yellow crinoid (? *Comanthina schlegeli*), 3 June 1978.

These specimens are provisionally referred to this species, which may prove to be a synonym of *P. affinis* (Zehntner). *P. brocketti* is known with certainty from the holotype specimen from the Maldives Islands (Borradaile, 1915; Bruce, 1978).

Periclimenes ceratophthalmus Borradaile

Heron Island, north west reef, outer slope, 60 ft., 1 ♂ on *Himerometra robustipinna*, 7 June 1979.

This species has been previously recorded in Australian waters only from One Tree Island (Bruce, 1977a) where it was found in association with the same host. Also known from the Maldiv Islands, Zanzibar, Kenya, the Seychelle Islands and Indonesia.

Periclemenes colemani Bruce

Known only from Heron Island, where the type material was collected from 36 ft., in association with the echinoid *Asthenosoma intermedium*, (Bruce, 1975a). One more specimen has since been collected from the same host at 30 ft., on 31 March 1977.

Periclemenes commensalis Borradaile

Heron Island, reef slope, 40 ft., crinoid host, 1 specimen 14 July 1976; 20 ft., crinoid host, 1 ♂, 1 ovigerous ♀, 17 April 1978; 20 ft., crinoid host, 3 specimens, 1 ovigerous ♀, 13 July 1978; 20 ft., 1 specimen on *Comanthus parvicirrus*, 14 July 1978. Wistari reef, north west slope, 95 ft., 3 specimens on crinoid host, 11 October 1976; reef slope, 80 ft., 1 specimen on *Comanthina schlegeli*, 6 April 1978; 1 ♂, 1 ovigerous ♀, 80 ft., on crinoid host, 7 April 1978; 1 specimen on crinoid, 40 ft., 10 April 1978; 3 specimens on *Comaster multifidus* at 70 ft., 9 July 1978.

Previously recorded from Australian waters in the Torres Straits (Borradaile, 1915) and from Moreton Bay (Bruce, 1971). Also known from East Africa to the Caroline and Solomon Islands, and New Caledonia. Not previously reported in association with *Comaster multifidus* or *Comanthina schlegeli*.

Periclimenes consobrinus De Man

Heron Island, southern reef flat, low water, one pair on *Pocillopora damicornis*, 12 August 1976.

Not previously recorded from Australian waters but some of the specimens reported from *Seriatopora* from Heron Island may have belonged to this species (Patton, pers. comm.) Otherwise known only from Ternate, Moluccan Islands, Kenya, Tanganyika and the Comoro Islands.

Periclimenes cornutus Borradaile

Wistari Reef, north east reef slope, 40-45 ft., 1 specimen, on *Himerometra robustipinna*, 21 July 1976.

The single example of this species is provisionally referred to this species, which may be a synonym of *P. amboinensis* (De Man). *P. cornutus* is known only from the type material from Male Atoll, Maldiv Islands.

Periclimenes cristimanus Bruce

Heron Island, Wistari Reef channel, 10 ft., on *Echinothrix calamaris*, 1 specimen, 18 August 1976; 1 ovig. ♀, 2 juv., 55 ft., same host, 7 June 1978.

Not previously recorded from Australian waters and reported only from Singapore, the type locality, Hong Kong and Pulau Perhentian Besae. The association with *Echinothrix* represents a new host record, as this species has only been so far recorded in association with *Diadema* spp.

Periclimenes diversipes Kemp

Heron Island, west end of reef flat, inner zone, low water, in *Porites andrewsi*, 5 ovigerous ♀, 8 June 1979.

Moderately common, but less abundant than *P. madreporae*. Adult females are generally smaller and easily distinguished by their colour pattern, with white speckling on pereopods. Of widespread distribution, throughout the Indian Ocean to Singapore. Previously recorded from Australia by Patton (1966) with specimens from Restoration Rock, Queensland, but not from Heron Island. An associate of a wide variety of corals, including *Psammocora*, *Pocillopora*, *Stylophora*, *Seriatopora*, *Acropora*, *Montipora*, *Pavona*, *Porites*.

Periclimenes elegans (Paulson)

Heron Island, central reef flat, low water, 1 ♂, 7 September 1976.

Although only one specimen is noted above, this species is quite commonly seen on the reef flat, where it occurs by day under dead coral bases, etc... First recorded from the Capricorn Islands by McNeill (1926) (as *P. elegans* var. *dubius*) and later from Northwest Cape by Balss (1921). McNeill also recorded this species from the Low Isles (1968), and it also occurs on the Diamond Islets, Swains Reef, Queensland. Otherwise known from the Red Sea to Marshall Islands.

Periclimenes galene Holthuis

Heron Island, reef slope, 60 ft., 1 ovigerous ♀ on hydroid (*Lytocarpus philippinus*), 17 September 1978. Wistari Reef, northern reef, 80 ft., 1 ♂ on *Lytocarpus philippinus*, 2 November 1978; 85 ft., on *Lytocarpus* sp., 3 ovigerous ♀, 20 November 1978.

Not previously recorded from Australian waters. Originally described by Ambon and Menado, Indonesia and more recently from Zanzibar, Tanganyika and Kenya. Common on *Aglaophenia* in East African waters.

Periclimenes goniopora Bruce

Heron Island, eastern reef, 20 ft., 1 ovigerous ♀ in *Montipora* sp., 21 July 1976; reef flat, low water, 1 specimen, on *Goniopora tenuidens*, 3 October 1976; reef flat pool, low water, 1 ovigerous ♀, on *Galaxea fascicularis*, 30 March 1978; 6 specimens (2 ovigerous ♀) on *Porites andrewsi*, low water, inner reef flat, 20 April 1979.

This species is new to the Australian fauna. It has only been previously recorded from East African waters, where it is associated with *Goniopora stutchberryi*, (Bruce, in press).

Periclimenes granulimanus Bruce

Wistari Reef, north reef slope, 80 ft., 1 specimen on a bushy hydroid, *Lytocarpus philippinus*, 7 April 1978.

Previously known only from the holotype specimen found in north west Madagascar in 1970 at Tany Keli, on an unidentified antipatharian. Found in association with *P. nilandensis*, *P. psamthe* and *P. toloensis*.

Periclimenes holthuisi Bruce

Heron Island, bommie, 40 ft., on unidentified anemone, 1 juvenile, 19 July 1976; sand bottom, 55 ft., 3 juveniles on unidentified alcyonarian, 19 October 1976. Wistari Reef, north west slope, sand, 2 ovigerous ♀, on *Catalaphyllia plicata*, 10 October 1976; north west slope base, 75 ft., sand near *Goniopora*, 3 specimens, 1 ovigerous ♀ on *Catalaphyllia*, 19 May 1978; south reef, 70 ft., 1 specimen on *Goniopora*, 20 December 1978.

Many more specimens have been observed but not collected. Frequently seen in deep water in association with *Periclimenes magnificus* on the coral *Catalaphyllia* or the anemone *Dofleini*.

Previously recorded from Bowen, Peloris Island and Moreton Bay, Queensland, in Australian waters (Bruce, 1971, 1977; Wadley, 1978). Also known from Zanzibar, the Seychelle and Maldiv Islands, Ceylon, Indonesia, New Guinea, Hong Kong, Japan, Caroline Islands and New Caledonia.

Periclimenes imperator Bruce

Wistari Reef, north west reef, 75 ft., 1 specimen on *Hexabranhus*

sanguineus, 11 October 1976. Several other examples have been observed, but not collected, on this host.

Previously recorded on Heron Island (Bruce, 1971, 1976a) and from Undine Reef, Orpheus and Lizard Islands. Occurs commonly throughout the Indo-West Pacific region from the northern Red Sea to Hawaii, often on *Hexabranchus* but also on a variety of holothurian hosts.

Periclimenes incertus Borradaile

Heron Island, bommie, 40 ft., several specimens on *Arenochalina flammula* (Lamm.), 20 July 1976. Wistari Reef, north east reef, 40-45 ft., 6 specimens, 3 ovigerous ♀, on *Leucetta microraphis* Haekel, 21 July 1976; in channel, 50 ft., 1 ovigerous ♀, host not located, 15 September 1976.

Previously recorded from Australian waters only from Northwest Cape (Balss, 1921, as *Palaemonella biunguiculatus*). Otherwise recorded from Aden, Kenya, Zanzibar, Tanganyika, Madagascar, Maldive and Andaman Islands, Ceylon and Indonesia. Both host species represent new host records.

Periclimenes inornatus Kemp

Heron Island, northern reef slope, 4 specimens, 2 ovigerous ♀, on *Radianthus* sp., 30-60 ft., 19 October 1976; outer reef slope, 36 ft., 4 specimens on *Radianthus* sp., 20 April 1978; north west reef slope,

Not previously recorded from Australian waters. Known from Zanzibar and Kenya, Comoro, Maldive and Andaman Islands and the South China Sea. Usually found on giant anemones in deeper water than *P. brevicarpalis*, which is common intertidally in many localities.

Periclimenes kemp Bruce

Heron Island, reef flat, low water, 1 ovigerous ♀, on *Microspicularia pachycladus*, coll. L. Shinkarenko, 16 August 1976; central reef flat pool, 4 specimens (3 ovigerous ♀), on *Limnalia peristyla*, 24 October 1976; idem, 5 specimens (2 ovigerous ♀), on *Sarcophyton* sp., 6 April 1978; idem, 4 specimens (1 ovigerous ♀) on *Sarcophyton* sp., 7 January 1978, reef slope, 12 specimens; 2 juveniles on *Nephtya* sp., 20 April 1978.

New to the Australian fauna, and apparently quite common on alcyonarians in shallow water. Previously recorded from only the Red Sea, Kenya, Zanzibar, Andaman Islands and Singapore. The associations with *Microspicularia* and *Limnalia* represent new host records.

Periclimenes lanipes Kemp

Wistari Reef, sand bottom, 1 km north of reef, 80 ft., 12 specimens, 11 juveniles, on *Euryale aspera*, 4 October 1978.

The specimens differ slightly from typical material in that postero-ventral angle of the pleuron of the fifth abdominal segment is acutely pointed.

Previously recorded in Queensland waters from Double Island Point (Bruce, 1971). Also known from Somalia, northern South China Sea, New Caledonia and Madagascar.

Periclimenes lutescens auct.

Common, usually in pairs, on corals of the genus *Acropora* at Heron Island. First reported from Heron Island by Patton (1966) and also recorded from Swains Reef (Bruce, 1977a). Known to occur from the Red Sea to Japan, and probably throughout the rest of the Indo-West Pacific region where branching species of *Acropora* are to be found.

Periclimenes madreporae Bruce

Common on a variety of coral hosts at Heron Island. This species was first reported from the locality as *P. inornatus* by Patton (1966). It has been found in association with *Pocillopora*, *Stylophora*, *Seriatopora*, *Acropora*, *Turbiniaria*, *Montipora* and *Acrhelia*. Known only from the Capricorn Islands and Solomon Islands.

Periclimenes magnificus Bruce

First described from specimens collected at Heron Island in association with the coral *Catalaphyllia plicata* at 80 ft., off Wistari Reef (Bruce, 1979). Several more specimens have been obtained from the same host and also from the anemone *Dofleinia armata*. The species is also now known to occur in Japan.

Periclimenes nilandensis Borradaile

Wistari Reef, northern reef slope, 80 ft., on *Lytocarpus philippinus*, 14 specimens, 7 April 1978.

Found in association with *P. psamathe*, *P. granulimanus* and *P. toloensis*. Not previously recorded as a hydroid associate.

New to the Australian fauna. Previously known from Zanzibar, Kenya, Madagascar, the Maldive Islands, Indonesia and the northern South China Sea, in association with gorgonians.

Periclimenes ornatellus Bruce

Heron Island, central reef flat, low water, 1 ♂, on unidentified anemone, 10 December 1978.

Previously recorded only from Eniwetok Atoll, Marshall Islands also on an unidentified anemone. The present specimen shows the same colour pattern as the type material and similar but less marked spinulations of the unguis of the dactyls of the ambulatory pereopods.

Periclimenes ornatus Bruce

Heron Island, bommie, 20 ft., 1 specimen on *Radianthus* sp., 21 July 1976.

Not previously recorded from Australia. Known from Kenya, Hong Kong, Japan and Marshall Islands only. In Japanese waters this species is associated with the anemones *Parasicyonis actinostroides* and *P. maxima* (Suzuki & Hayashi, 1977).

Periclimenes psamathe De Man

Wistari Reef, north east reef slope, 80 ft., 73 specimens on *Lytocarpus philippinus*, 7 April 1978; 16 specimens, 80 ft., same host, 2 November 1978; 11 juveniles, 85 ft., same host, 20 November 1978.

The above specimens were associated with *P. galene*, *P. nilandensis* and *P. granulimanus* as well as *P. toloensis*. Recorded previously from East Africa, Madagascar, Chagos and Maldives Islands, Indonesia, South China Sea, Japan, Caroline Islands and New Caledonia. Not previously recorded from Australia. Earlier records have indicated associations with gorgonian hosts and this species has not been previously found on hydroids.

Periclimenes seychellensis Borradaile

Collected frequently, but only in small numbers; mainly from regions of algal growth on the reef flat.

Not previously recorded from Australian waters but common throughout the Indian Ocean, Singapore, Indonesia, to Papua. A free-living micro-predator, without commensal associations.

Periclimenes soror Nobili

A common associate of asteroids on Heron Island and Wistari Reefs, extending from the reef flat down to a depth of 100 ft. The commonest host is probably *Acanthaster planci* but other hosts include *Culcita novaeguineae*, *Echineaster luzonicus* and 5 specimens have been collected

on *Halityle regularis*. *Halityle regularis* and *Echineaster luzonicus* represent new host records.

Two conspicuous colour forms occur; red and white on *Acanthaster* and purple on *Culcita* and other hosts.

First recorded in Australian waters from Green and Fairfax Islands (Bruce, 1971) and extending south to Cutaway, New South Wales, while also occurring in the Dampier Islands, Western Australia (Bruce, 1976). Common throughout the Indo-West Pacific region from the Red Sea to Hawaii and the Tuamotu Islands, as far east as Panama.

Periclimenes spiniferus De Man

Probably the most abundant pontonine shrimp, at least on the reef flat, where it occurs in the bases of live and dead coral colonies in large numbers.

First recorded in Australian waters from Northwest Islet, Capricorn Islands, by McNeill (1926) and also reported from Heron Island by Patton (1966) and the Low Isles by McNeill (1968). Widely distributed throughout most of the Indo-West Pacific region, except the north west, from Kenya to Tahiti. A free-living species.

Periclimenes tenuipes Borradaile

Wistari Reef, in coral cave, 80 ft., 1 ♂, 2 ovigerous ♀, coll. W. Deas, 13 July 1976; northern part of reef, 45 ft., 1 specimen, 30 March 1977.

Not previously recorded from Australian waters. Recorded in small numbers from East Africa to the Marshall Islands. Usually appears free-living but also reported to be associated with anemones (Reed, 1974).

Periclimenes tenuis Bruce

Heron Island, reef slope, 1 specimen on *Himerometra magnipinna*, 9 July 1978; 1 ♂, 2 ovigerous ♀, Wistari Reef, on crinoid, 13 July 1978.

New to the Australian fauna. Previously recorded only from Zanzibar and Eylath, northern Red Sea. Previously found in association with *Tropiometra carinata* and *Heterometra carinata*.

Periclimenes toloensis Bruce

Wistari Reef, north west slope, 80 ft., on hydroid, *Lytocarpus philippinus*, 7 April 1978; northern reef slope, 80 ft., 6 specimens (2 ovigerous ♀), same host, 2 November 1978.

New to the fauna of Australia. Previously recorded only from the type locality Tolo Channel, Hong Kong, and from Zanzibar. The host of the type species was not identifiable and these records present the first host records for this species.

Philarius gerlachei (Nobili)

Patton (1966) recorded 4 specimens from *Acropora* at Heron Island. A dozen more specimens were obtained since, all from *Acropora* colonies in shallow water. Both this species and *P. imperialis* are distinctly less common than *Periclimenes lutescens*.

Also known from Willis Island, Bet Reef and Restoration Rock in Australian waters, its range extends from the Red Sea to the Samoan Islands.

Philarius imperialis (Kubo)

Three specimens were recorded by Patton (1966) from *Acropora* colonies at Heron Island. A further 15 specimens have since been collected from the same hosts, down to a depth of 65 ft.

The distribution of this species extends from the northern Red Sea to the Marshall Islands.

Philarius lifuensis (Borradaile)

Heron Island, south west slope, 20 ft., on *Acropora* sp., 1 ♂, 1 ovigerous ♀, 30 July 1976; north west reef slope, 40 ft., on *Acropora* sp., 1 ♂, 1 ovigerous ♀, 29 May 1979. Wistari Reef, 60 ft., on *Acropora* sp., 1 ♂, 1 ovigerous ♀, 14 September 1976; in channel 60 ft., on *Acropora* sp., 1 ♂, 1 ovigerous ♀, 15 September 1976.

This rare species has not been previously recorded from Australian waters and is known only from the holotype specimen collected from Lifu, Loyalty Islands and described by Borradaile in 1898. Like other species of the genus, it is an associate of *Acropora* corals but appears to inhabit greater depths and does not occur on the reef flat. It is to be redescribed in detail elsewhere.

Platycaris latirostris Bruce

Heron Island, eastern reef slope, 50 ft., 1 pair, in *Galaxea fascicularis*, 14 June 1979.

Not previously recorded from Australian waters. Known from Kenya, Zanzibar, Tanganyika, Mocambique, Madagascar, Comoro and Seychelle Islands and Indonesia.

The present specimens were found in association with specimens of *Ischnopontonia lophos* and *Racilius compressus*. All are specific to *Galaxea fascicularis*.

Pliopontonia furtiva Bruce

Wistari Reef, reef slope, 25 ft., on zoanthid, 1 ♂, 1 ovigerous ♀, 7 May 1979.

First recorded from Australian waters at Heron Island by N. Coleman (1977). Originally described from Kenya and not known from other localities as yet. The types were associated with the corallimorph *Rhodactis rhodostoma*.

Pontonia ardeae Bruce

Three pairs of specimens were collected from Wistari Reef, in *Chama pacifica* at a depth of 60 ft. on 3 May 1979. These are the type specimens and only known examples of this species as yet (Bruce, in press a).

Pontonia katoi Kubo

Wistari Reef, 80 ft., 1 ♂, 1 ovigerous ♀ in *Cnemidocarpa pedata*, coll. C. Hawkins, 6 November 1978; 1 ovigerous ♀, 60 ft., 3 May 1979. Heron Island, 2 ♂, 2 ovigerous ♀ in *Styela* sp., 15 December 1978; 3 specimens (1 ovigerous ♀) in *Polycarpa* sp., 4 May 1979; 3 specimens in *Polycarpa* sp., 40 ft., 29 May 1979.

Several closely related species have also been collected but *P. katoi* is always readily distinguished by its characteristic colour pattern.

Previously recorded from Australian waters at Coil Reef, Queensland (Bruce, 1977). Also known from Tanganyika, Indonesia and Japan. The association with *Cnemidocarpa* represents a new host record. Previous hosts include *Herdmania*, *Cynthia*, *Polycarpa*, *Styela* and *Microcosmos*.

Pontonia okai Kemp

Heron Island, 1 juvenile, from unidentified ascidian, coll. J.E.N. Veron, 24 May 1977. 1 ♂, 1 ovigerous ♀, in *Ascidia* sp., 50 ft., 5 June 1979.

This species has not been previously recorded from Australia and is known only from the type locality off Cape Negrais, Burma, and from Kenya, Indonesia and the northern South China Sea.

Pontonides sp. aff. *unciger* Calman

Wistari Reef, 75 ft., on *Cirripathes anguinis*. 1 ♂, 1 ovigerous ♀. coll. N. Quinn, 2 December 1978.

This pair of specimens are considered to be conspecific with those reported upon and illustrated by Davis and Cohen (1968), which are distinct from *P. unciger* Calman s. str.

Pontoniopsis comanthi Borradaile

Heron Island, isolated bommie on south east reef, 20 ft., 1 specimen on *Comatula pectinata*, 31 July 1976; idem, 20 ft., on crinoid, 1 ♂, 1 ovigerous ♀, 17 April 1978; 1 ovigerous ♀, crinoid, 13 July 1978. Wistari Reef, 70 ft., on *Capillaster multiradiatus*, 9 July 1979; on *Comatula purpurea*, 40-65 ft., 1 ♂, 1 ovigerous ♀, 15 September 1976.

First described from Australia, from specimens from Mabuaig, Torres Straits, and subsequently recorded from the Red Sea, Kenya, Zanzibar, Indonesia and the Marshall Islands. The host records have been previously noted in Bruce (1979a).

Propontonia pellucida Bruce

Heron Island, southern reef flat, low water, 1 ♂, 1 ovigerous ♀, on *Lobophyton* sp., coll. M. Bruce, 28 September 1977.

Not previously recorded from Australia. This record is the first indication of the occurrence of this species outside the Indian Ocean, where it has been recorded, in association with alcyonarians, from Zanzibar, Kenya, the Comoro Islands and the Seychelle Islands.

Stegopontonia commensalis Nobili

A single example of this species was recorded by Gillett and McNeill (1959), from *Diadema setosum*. No further specimens of this species have been obtained.

Sparsely distributed from Kenya to Hawaii. No records from elsewhere in Australian waters.

Thaumastocaris streptopus Kemp

Heron Island, south eastern reef, on bommie, 40 ft. in *Arenochalina flammula*, 1 juvenile, 20 July 1976. Wistari Reef, north east reef, 40-45 ft., in *Leucetta microraphis*, 1 specimen, 21 July 1976.

Not previously recorded from Australian waters. First reported

from Noumea, New Caledonia, and also known from East Africa, Madagascar, Indonesia and the Marshall Islands.

This sponge associate has been previously reported in association with sponges of the genera *Siphonochalina*, *Callyspongia*, *Haliclona*, *Petrosia*, *Acarnus* and so *Leucetta* and *Arenochalina* represent new host records.

Typton australis Bruce

Heron Island, southern reef flat, low water, in sponge, 1 ♂, 1 ovigerous ♀, 10 January 1979.

Previously known only from the type specimen collected from Chinaman's Reef, Queensland (Bruce, 1973). Not recorded from outside Australian waters.

Typton bawii Bruce

Heron Island, western reef flat, low water, in sponge, 1 ovigerous ♀, 17 January 1979.

Not previously recorded from Australian waters. First recorded from Zanzibar, and subsequently from Kenya, in association with the sponge *Iotrochota baculifera*.

Typton dentatus Fujino & Miyake

Heron Island, reef flat, in rubble, low water, in *Reniera* sp., 1 ♂, 1 ♀, 4 January 1979.

Previously known only from the type specimens collected in the Ryukyu Islands. The host sponge had not been previously identified.

Typton wasini Bruce

Heron Island, reef slope, 70 ft., in *Dysidea* sp., 3 specimens, 6 May 1976; central reef flat, low water, in sponge, 2 ♂, 3 ovigerous ♀, 11 November 1976; southern reef slope, 37 ft., 3 specimens (1 ovigerous ♀), in sponge, 9 May 1978; southern reef crest rubble, in sponge, low water, 1 ♂, 3 June 1978; Shark Bay, in sponge in coral rubble, low water, 1 specimen, 8 June 1978.

Not previously recorded from Australian waters and known only from the type locality, Wasin Island, Kenya. One lot of specimens (8 June 1978) were found in a sponge in association with an undescribed species of *Typton*.

Zenopontonia noverca (Kemp)

Heron Island, 80 ft., 5 specimens, on *Pentaceraster regularis*, 22 February 1978. Wistari Reef, north west slope base, 80 ft., on *Pentaceraster* sp., 16 April 1977; idem, 1 ♂, 1 ovigerous ♀, 75 ft., on asteroid, 16 July 1977.

Previously reported from Bowen, Queensland (Bruce, 1971, 1975). Otherwise reported from the type locality, Noumea, New Caledonia, Zanzibar and Madagascar only. The association with *Pentaceraster regularis* represents a new host record. The previously reported hosts include *Pentaceraster alveolatus*, *P. tuberculatus* and *P. mammillatus* as well as *Culcita*, *Protoreaster* and *Halityle* spp.

DISCUSSION

This report confirms the presence of 100 species of previously described pontoniine shrimps, belonging to 31 different genera, on the Heron Island-Wistari reefs, at the southern end of the Great Barrier Reef system. Of these, 47 species are recorded from Australian waters for the first time. A number of undescribed species have also been collected during the course of this study, but are not included in this report. These belong particularly to the genera *Periclimenaeus*, associated with sponges and ascidians, and *Pontonia*, also associated with ascidians. This study, carried out from 1976 to 1979, provides a detailed picture of the variety of pontoniine shrimps occurring in a restricted coral reef locality, although it is certain that more species remain to be identified. Little comparable data exists for the number of species of this subfamily that occur in similarly restricted localities in other parts of the tropics, or for other coral reefs. Such studies as have been carried out appear to have been of a more general nature, spread over wider areas, or over shorter periods of time. There is no reason to suppose that the Heron Island-Wistari reef pontoniine fauna is particularly rich and it is likely that similar studies of other subtropical reefs would produce evidence of a similar number of species. More tropical reefs could well possess a richer fauna, as some biotopes, such as sea grass beds, are lacking from the Heron Island reefs, and some groups of potential hosts, such as echinoids and bushy gorgonians, are poorly represented. Of the species recorded from Heron Island reefs only six, *Paranchistus pychnodontae*, *Periclimenaeus diplosomatis*, *Periclimenaeus pachydentatus*, *Periclimenes colemani*, *Pontonia ardeae* and *Typton australis*, all fairly recently described, have not yet been found to occur in non-Australian waters. There is no reason to suppose that these species are endemic.

Most of the species recorded are of widespread Indo-West Pacific distribution, ranging from the Red Sea and East Africa to the Hawaiian Islands. Of the 100 species recorded, 75 are also known from the western Indian Ocean, 10 species are known from Hawaii (out of the 18 pontoniine shrimps known to occur there), and 4 species also range as far east as the western seaboard of America (*Periclimenes soror*, *Harpiliopsis depressa*, *Harpiliopsis spinigera* and *Fennera chacei*).

Table 1

Species	Hosts	Porifera	Hydrozoa	Antipatharia	Alcyonacea	Gorgonacea	Pennatulacea	Corallimorpharia	Actinaria	Scleractinia	Gastropoda	Bivalvia	Crinoidea	Holothuroidea	Echinoidea	Asteroidea	Ophiuroidea	Ascidacea	Free-living	Reef flat	Reef slope	Slope base
1 <i>Allopontonia iaini</i> *															x							x
2 <i>Anchistioides compressus</i> *		x																			x	
3 <i>Anchistioides willeyi</i>		x																			x	
4 <i>Anchistus custoides</i>												x										x
5 <i>Anchistus demani</i>												x								x		
6 <i>Apopontonia falcistrostris</i> *		x																			x	
7 <i>Conchodytes meleagrinae</i>												x								x		
8 <i>Conchodytes tridacnae</i>												x								x		
9 <i>Corraliocaris graminea</i>										x										x	x	
10 <i>Coralliocaris superba</i>										x										x	x	
11 <i>Coralliocaris venusta</i>										x										x	x	
12 <i>Coralliocaris viridis</i>										x										x		
13 <i>Dasella herdmaniae</i> *																		x			x	
14 <i>Dasycaris ceratops</i>							x															x
15 <i>Hamodactylus agabai</i> *					x																x	
16 <i>Hamodactylus boschmai</i> *						x															x	
17 <i>Hamodactylus noumeae</i> *						x															x	
18 <i>Hamopontonia corallicola</i>										x										x	x	
19 <i>Harpiliopsis beaupresii</i>										x										x		
20 <i>Harpiliopsis depressa</i>										x										x		
21 <i>Harpiliopsis spinigera</i> *										x										x	x	
22 <i>Ischnopontonia lophos</i>										x											x	
23 <i>Jocaste japonica</i>										x										x	x	
24 <i>Jocaste lucina</i>										x										x	x	
25 <i>Onycocaris amakusensis</i> *		x																		x		
26 <i>Onycocaris monodoa</i> *		x																		x		
27 <i>Onycocaris oligodentata</i> *		x																			x	
28 <i>Palaemonella pottsi</i>													x								x	
29 <i>Palaemonella rotumana</i>																			x	x	x	
30 <i>Palaemonella spinulata</i>																			x		x	
31 <i>Paranchistus pycnodontae</i> ⁺⁺												x								x		
32 <i>Parapontonia nudirostris</i> *														x							x	
33 <i>Paratypton siebenrocki</i>										x										x		
34 <i>Periclimenaeus arabicus</i>		x																		x	x	
35 <i>Periclimenaeus ardeae</i>		x																		x		
36 <i>Periclimenaeus bidentatus</i>		x																			x	
37 <i>Periclimenaeus diplosomatis</i> ⁺⁺																		x		x		
38 <i>Periclimenaeus djiboutensis</i> *		x																			x	
39 <i>Periclimenaeus gorgonidarum</i> *		x																			x	
40 <i>Periclimenaeus hecate</i>																		x		x	x	
41 <i>Periclimenaeus odontodactylus</i> *		x																			x	
42 <i>Periclimenaeus ornatus</i>		x																		x		
43 <i>Periclimenaeus pachydentatus</i> ⁺																		x			x	

Species	Hosts	Porifera	Hydrozoa	Antipatharia	Alcyonacea	Gorgonacea	Pennatulacea	Corallimorpharia	Actiniaria	Scleractinia	Gastropoda	Bivalvia	Crinoidea	Holothuroidea	Echinoidea	Asteroida	Ophiuroidea	Ascidacea	Free-living	Reef flat	Reef slope	Slope base
89 <i>Pontonia katoi</i>																		x			x	
90 <i>Pontonia okai</i> *																		x			x	
91 <i>Pontonidea aff. unciger</i> *				x															x		x	
92 <i>Pontoniopsis comanthi</i>													x								x	
93 <i>Propontonia pellucida</i> *					x															x		
94 <i>Stegopontonia commensalis</i>															x					x		
95 <i>Thaumastocaris streptopus</i> *		x																			x	
96 <i>Typton australis</i>		x																		x		
97 <i>Typton bawii</i> *		x																		x		
98 <i>Typton dentatus</i> *		x																		x		
99 <i>Typton wasini</i>		x																		x	x	
100 <i>Zenopontonia noverca</i>																x					x	

* Species new to Australia

+ Species not known outside Australian waters

++ Species known only from Heron Island

Six of the species collected are considered to be free-living, - *Palaemonella rotumana*, *P. spinulata*, *Periclimenes elegans*, *P. seychellensis*, *P. spiniferus* and *P. tenuipes*, although one of these, *P. tenuipes*, has been reported from the Palau Islands as a commensal of anemones and feeding upon the host's mucus (Read, 1974). No species have been noted as indulging in fish-cleaning behaviour, as has been recorded for several closely related species of *Periclimenes* occurring in the Caribbean region.

The remaining 94 species are commensal associates of various other marine invertebrates, that is to say, they are to be found in permanent obligatory associations with selected host animals only and not in other situations (Bruce, 1976a). These associations are summarized in table 1. The range of host animals is extensive and involves five phyla. The choice of hosts is dominated by the Coelenterata, with 41 species of associated shrimp, of which 24 are commensals of scleractinian corals. Fourteen genera are associated with coelenterates and ten with the scleractinia. The Porifera are hosts for 21 species of seven genera and the Echinodermata are hosts to 18 species of six genera only. Of the remaining 14 species, 7, of three genera, are associates of ascidians, and 7, of five genera, are commensals of molluscs. Of particular interest is the occurrence of five species in association with hydroids which have rarely been recorded as hosts for commensal shrimps. These hydroid associates have been associated with gorgonians in other parts of their ranges.

The purpose of the present study is to assess the diversity of the caridean fauna at a simple restricted coral reef locality. Several studies have provided data on the caridean fauna of tropical localities but unfortunately their results can not be considered to be strictly comparable. The methods employed have been different or not described, and the emphasis, extent, depth range and duration of sampling have generally not been clearly indicated. The extensive use of scuba techniques during the Heron Island survey have enabled many species to be collected that would not have otherwise been obtained.

Localities for which some comparable information is available include Inhaca Island, southern Mocambique (MacNae & Kalk, 1958); Eylath, Gulf of Aqaba (Holthuis, 1958); Singapore (Johnson, 1960); Malindi, central Kenya (Bruce, 1970) and Amakusa Island, southern Japan (Kikuchi & Miyaki, 1978). The Malindi study was based on a 3 day survey only, and the species list can not be considered as anywhere near complete. The other surveys all appear to have covered a considerable period of time. Johnson (1960) considered that the Singapore fauna was impoverished due to fresh water influence, but some species have recently been added to his list and are included in the Singapore total (Bruce, 1979a). The results of these studies are summarized below:-

<u>Locality</u>	<u>Genera</u>	<u>Species</u>
Eylath	7	12
Malindi	13	32
Inhaca Island	6	10
Singapore	11	28
Amakusa Island	9	17
Heron Island	31	100
Heron Island reef flat only	15	47

It is quite certain that further detailed study of the caridean fauna of all these localities would produce a considerable increase in the number of species recorded, so that the apparent discrepancy in numbers would be less marked. The number of species recorded from Heron Island, together with some new species as yet undescribed, suggests that a pontonine fauna of about 150 species is probably present above a depth of 30 metres. Possibly more tropical localities will support a richer fauna. It may be noted that the Heron Island fauna is comparable with that of Zanzibar Island (Bruce, 1974), which has 91 species of 28 genera. Many of the species are common to both localities. Zanzibar is a large island, with an extensive leeward reef system, with extensive areas of mangrove, sea grasses and muddy or silty substrates that are not represented at Heron Island, although present at many other localities on the Great Barrier Reef.

It is probable that, for the localities listed, collection was mainly limited to reef flat or shallow water species. In table 1, the habitats of the various Heron Island species are approximately indicated, although the division of habitats into reef flat, slope and base is not precisely defined. This classification indicates that 47 species of fifteen genera are present on the reef flat, a total much closer to that of the other localities. The classification also indicates that the species diversity on the slope is higher than on the reef, with 64 species of 23 genera being present. The species found in the two regions are largely mutually exclusive, only 16 being found in both zones, and of these, 9 are associates of scleractinian hosts.

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**NUMERICAL CLASSIFICATION OF 'MIXED SCRUB'
VEGETATION ON ALDABRA ATOLL**

by D. McC. Newberry and M. G. Hill

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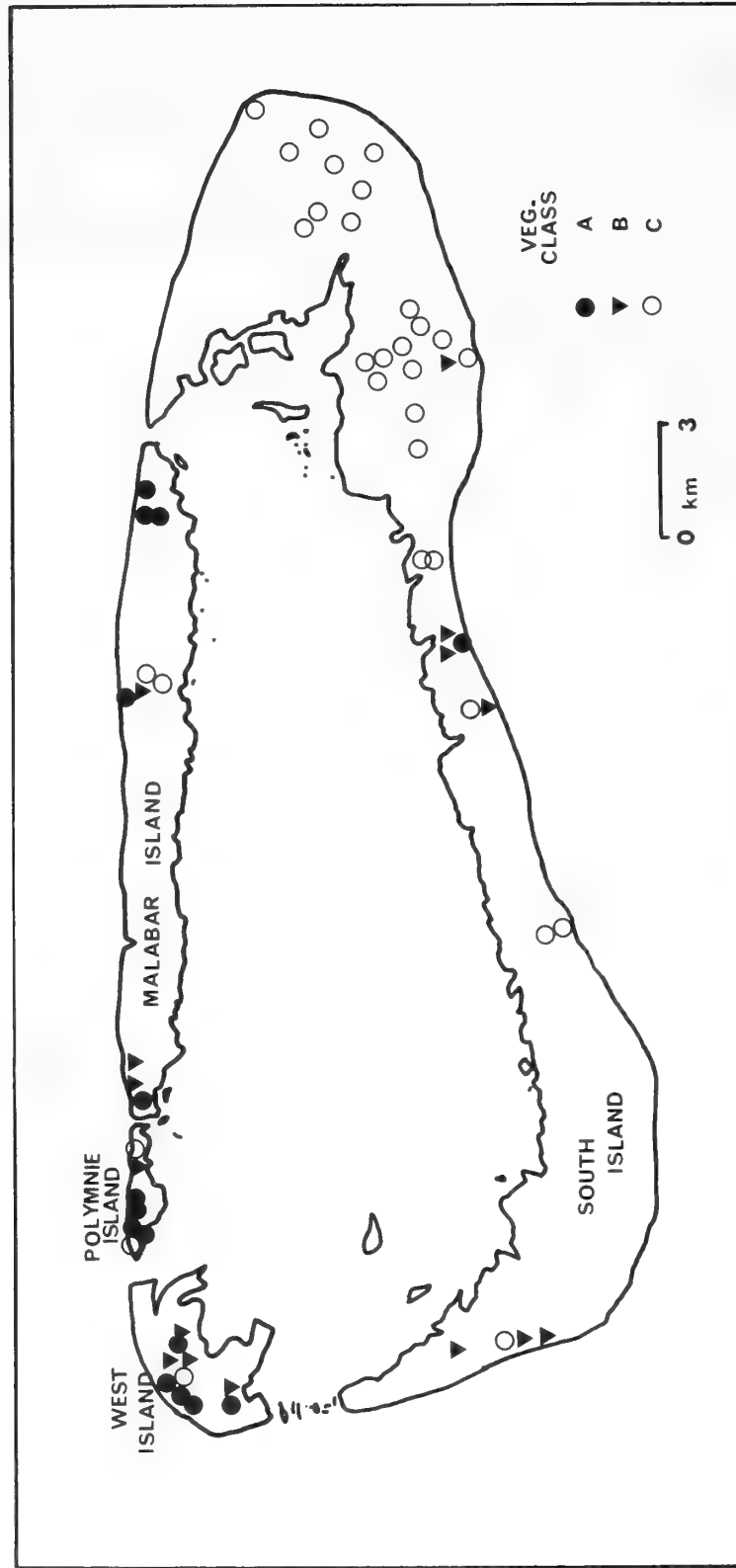


Fig. 1. Aldabra Atoll showing the position of Sixty-one sites given in three classes of mixed-scrub vegetation.

NUMERICAL CLASSIFICATION OF 'MIXED SCRUB' VEGETATION ON ALDABRA ATOLL

by D. McC. Newberry¹ and M. G. Hill

INTRODUCTION

Previous qualitative descriptions of the vegetation of Aldabra Atoll (46° 20' E, 9° 24' S) defined three major woody vegetation types: (a) mangroves, (b) *Pemphis acidula* scrub, and (c) 'mixed-scrub' (Fosberg, 1971; Hnatiuk and Merton, 1979; Stoddart and Wright, 1967). Mixed scrub varies considerably in its floristic composition over the whole atoll but has received little detailed analysis.

This paper reports the results of a classification of mixed-scrub which formed part of a survey of the status of infestation of the coccid, *Icerya seychellarum* (Westw.) in 1976/7 to 1978 (Hill and Newberry, 1980).

METHODS

Between 4 December 1976 and 25 February 1977 the percentage cover, density and height of each woody taxon were recorded in 61 sites representative of Aldabra's mixed scrub (Fig. 1). Although convenience of access largely determined the areas sampled, vegetation adjacent to paths was avoided.

The ground area covered by woody living and dead vegetation was recorded for each site. Where the vegetation was stratified the total percentage cover of all the species in a site exceeded the ground cover.

The topography of the sites was recorded in three classes described by Stoddart *et al.* (1971): (i) champignon, (ii) pavé, and (iii) platin limestone coral. Position of each site in relation to the sea coast and the '8 m ridge' (Stoddart *et al.*, (1971) which is prominent along some of the atoll's rim, was noted.

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RESULTS

The percentage cover data for 56 woody taxa (Appendix 1) plus two partly woody ground layer taxa were classified by a polythetic divisive procedure. This method separates groups of sites on the basis of a reciprocal averaging ordination of species and sites (Hill, 1973; A.J. Morton and J.W. Bates, pers. comm.).

The mixed-scrub sites were clearly divisible into three main classes (A, B and C) and nine subclasses (Fig. 2). The mean percentage cover of each taxon in each subclass is recorded in the appendix.

Sites in classes A and B predominated in the north and northwest of the atoll (Fig. 1) whilst those in class C were in the south and southeast. For those taxa which had a mean percentage cover exceeding 5% in any subclass, eight were common to all three main classes, four to A alone, three to B alone and seven to C (Table 1).

The mean density and percentage ground cover of living woody vegetation were greater in classes A and B than in C (Table 2), and the vegetation in class C sites was taller and had a greater percentage of dead material than A or B.

Four of the nine subclasses are specialized vegetation types: (i) A2, coastal *Casuarina* woodland; (ii) A3, *Scaevola* dominated coastal scrub; (iii) C3, *Thespesia-Lumnitzera* very open low-lying vegetation around lagoon inlets in SE., and (iv) C4, Takamaka grove, dominated by *Calophyllum*. These have been recognized by Hnatiuk and Merton (1979) and Fosberg (1971). (Full taxonomic nomenclature is given in the appendix).

The remaining five subclasses are floristically more diverse and represent the bulk of the inland mixed-scrub of Aldabra. From notes on the position and topography of the sites it is possible to distinguish some factors associated with the subclasses.

- (a) A1. Dense, tall mixed-scrub in the north and northwest on champignon, inland of the '8 m ridge'.
- (b) B1. Dense, tall mixed-scrub in the north and northwest on pavé on, and inland of, the ridge.
- (c) B2. Shorter, open mixed-scrub on pavé on the ridge in the south.
- (d) C1. Open mixed scrub on pavé and platin in the south and southeast.
- (e) C2. Open, tall mixed-scrub and woodland on platin in the east.

Table 1 shows that A1 and B1 are distinguished from C1 and C2 by the higher cover of *Acalypha claoxyloides*, *Pemphis acidula*, *Sideroxylon inerme* and *Tarenna supra-axillaris* and by the absence of very low cover of *Ochna ciliata*, *Apodytes dimidiata*, *Canthium bibracteatum* and *Guettarda speciosa*. *Maytenus senegalensis*, *Myrtroxylon aethiopicum* and *Polysphaeria multiflora* were present with appreciable cover in most of the sites of these subclasses.

Subclass A1 differs from B1 because it has much higher cover of *Tricalysia sonderiana* and *Allophylus aldabricus*, but little *Euphorbia pyrifolia* and *Dracaena reflexa* (Table 1). The percentage cover of *Acalypha claoxyloides* was much higher, and of *Tarenna supra-axillaris* much lower, in A1 than in B1. Subclass C1 has a greater cover of *Maytenus senegalensis* and *Guettarda speciosa* than C2 but much less *Canthium bibracteatum* and *Terminalia boivinii* than C2.

Classification imposes artificial divisions on the floristic structure of the vegetation where they might not exist in the field. The above subclasses may be expected to form a continuum. The distribution of the sites with respect to the first two components of an ordination (Orloci 1966) show very close agreement with the arrangement of the sites in the classification (Fig. 3). Subclass A2 sites have been removed as a first ordination showed that they were well separated from the rest of the sites. Axes I and II accounted for 18% and 12% respectively of the total variance. One simple interpretation of these axes is that II follows a northwest to southeast gradient (-ve to +ve Fig. 3) and I a topographical gradient from champignon to platin (+ve to -ve). Axis I may also be confounded with the effects of salinity since coastal sites are grouped in the bottom left of Fig. 3.

DISCUSSION

The aim of the vegetation sampling was to assess the population of the coccid, *I. seychellarum*, on Aldabra and the use of the classification has aided the interpretation of coccid data (Hill and Newbery, 1980).

As the sites were (a) not strictly randomly located, (b) did not cover all the mixed-scrub of Aldabra (notably the NE of South Island), and (c) may be considered insufficient in number, the classification presented here has limitations. However, the results are clear. Since numerical records of the floristic composition of mixed-scrub have not been published before and Aldabra's vegetation has not received quantitative treatment we consider it important to present our findings fully. These data may form a basis for further study of the vegetation but need improvement and expansion. Our classification does not include grasses and herbs since coccids are restricted to woody plants.

Stoddart *et al.* (1971) have described the marked change in topography across the atoll, from a predominance of champignon in the north-west, through pavé, to platin limestone areas in the south-east. Topography also changes from sea-coast to lagoon, with the 8 m ridge providing a mosaic of small, soil-filled pockets. The classification emphasizes the influence of topography in the differences between vegetation classes and subclasses both within and between islands of the atoll. To speculate any further on the reasons for the differences in floristic composition would be dangerous without experimental evidence on the response of different tree taxa to different edaphic regimes. Two other major factors change between the NW and SE of the atoll: (i) There is a greater density of Aldabra's main herbivores (tortoises and goats) towards the eastern end and (ii) there is greater exposure to SE trade winds in the dry season along the south and south-east coast compared with the more sheltered islands in the north-west (Hnatiuk and Merton, 1979). There is some indication that rainfall may differ across the island, but evaluation of this awaits full analysis of data collected between 1975 and 1979.

Sites were chosen to be representative of different vegetation found in different parts of the atoll. It is therefore not surprising that the classes in Fig. 2 are so well defined. Had more sites been placed on the borders of different vegetation types (if such types really exist) a less clear subdivision of the sites would have resulted. However, the classification did permit the comparison between 30 sites in classes A and B in the north-west with 31 sites in class C in the south-east, and identified the main differences in floristic composition.

Ordination of the sites suggests that the mixed-scrub forms a continuum across the atoll and explains the difficulty presented to previous workers to subdivide it beyond the more obvious specialized subclasses shown above (Hnatiuk and Merton 1979). The ordination showed no discrete groups of sites. The first three axes removed only 40% of the total variation, and this indicates that several important factors influence floristic composition. Further studies of mixed-scrub would be more effectively analysed as a continuum rather than by classification, which met our rather restricted aims in studying the coccid distribution.

SUMMARY

Sixty-one mixed-scrub sites on Aldabra Atoll have been numerically classified into three main classes and nine subclasses, and these are associated with differences in topography and position on the atoll. Ordination of the sites suggests that the vegetation is more realistically viewed as a continuum.

ACKNOWLEDGEMENTS

We thank Dr. N. Waloff and Prof. A.J. Rutter for their advice and encouragement, the Royal Society for facilities on Aldabra and the Natural Environment Research Council for financial support. We are grateful to Mr. S.A. Renvoize of the Royal Botanic Gardens, Kew for checking species authorities and Dr. A.J. Morton for the use of computer programs. Professor T.R.E. Southwood is thanked for providing facilities at Silwood Park and commenting on this paper, and Dr. C.W.D. Gibson for useful discussions.

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Table 1. Mean percentage cover of woody taxa in eight subclasses (A1-C3) that exceed 5% cover in any subclass.
(for taxon authorities see Appendix)

Taxa	A1	A2	A3	B1	B2	C1	C2	C3
<i>Maytenus senegalensis</i>	8.1		5.3	14.7	11.1	15.9		
<i>Acalypha claoxyloides</i>	30.5	60.0		5.7				
<i>Pemphis acidula</i>	9.4			12.6				
<i>Polysphaeria multiflora</i>	8.8			8.2	9.8	13.9	22.7	
<i>Tarenna supra-axillaris</i>	5.9			19.3				
<i>Sideroxylon inerme</i>	9.8			10.1				
<i>Mystroxydon aethiopicum</i>	17.7			21.6		16.0	8.7	
<i>Terminalia boivinii</i>	6.3			17.5			5.6	
<i>Tricalysia sonderiana</i>	6.8							
<i>Allophylus aldabricus</i>	5.1							
<i>Casuarina equisetifolia</i>		62.5						
<i>Scaevola taccada</i>			15.6					
<i>Euphorbia pyrifolia</i>				7.1	10.8			
<i>Dracaena reflexa</i>				6.0				
<i>Colubrina asiatica</i>					10.3			
<i>Ochna ciliata</i>						7.0	15.1	8.4
<i>Apodytes dimidiata</i>						10.4	6.5	
<i>Guettarda speciosa</i>						6.5		
<i>Canthium bibracteatum</i>							6.1	
<i>Pandanus tectorius</i>								6.0
<i>Thespesia populneoides</i>								10.4
<i>Lumnitzera racemosa</i>								5.3

Table 2. Mean density, percentage of ground covered by living and dead vegetation and mean and maximum height of woody vegetation in 9 subclasses of Aldabra mixed-scrub.

Vegetation class	Density (400 m ⁻²)	% cover		height (m)	
		alive	dead	mean*	max. +
A1	277	91	2.2	1.5	3.4
2	152	84	2.5	1.5	8.6
3	113	58	4.5	1.0	2.6
B1	298	90	2.9	1.8	2.7
2	189	62	2.5	1.3	2.3
C1	141	73	3.5	1.5	2.6
2	129	70	1.3	1.8	2.8
3	41	42	9.0	2.2	2.8
4	76	87	13.3	4.2	9.0

*mean of all taxa in site

+the mean of the three tallest taxa

Appendix. Percentage cover of taxa averaged for the sites in each of the vegetation subclasses A1 to C4 (C4 consists of 1 site and its values appear below the table)

	A1	A2	A3	B1	B2	C1	C2	C3
<i>Acalypha claoxylloides</i> Hutch.	30.5	60.0	2.1	5.7	3.4	1.2	1.6	.
<i>Achyranthes aspera</i> L.	0.4	.	0.6	0.3	.	.	.	.
<i>Allophylus aldabricus</i> Radlk.	5.1	1.0	.	4.0	0.3	0.7	0.5	0.8
<i>Apodytes dimidiata</i> E. Mey. ex Arn.	0.9	.	.	4.4	2.4	10.4	6.5	2.5
<i>Asparagus umbellulatus</i> Bresler	0.1	.	.	.	.	.	.	.
<i>Azima tetracantha</i> Lam.	2.0	.	1.9	1.1	0.1	0.5	.	.
<i>Caesalpinia bonduc</i> (L.) Roxb.	0.4	.	.	.	.	.	.	.
<i>Calliandra alternans</i> Benth.	.	.	.	.	.	.	0.7	.
<i>Canthium bibracteatum</i> (Bak.) Hiern	1.3	.	.	2.1	.	1.0	6.1	0.2
<i>Capparis cartilaginea</i> Decne	1.7	1.0	0.6	.	0.3	0.1	0.8	.
<i>Casuarina equisetifolia</i> L.	.	62.5	1.5	.	.	.	.	.
<i>Clerodendrum glabrum</i> E. May. var. <i>minutiflorum</i> (Bak.) Fosb.	1.3	.	.	1.4	1.6	1.0	.	.
<i>Colubrina asiatica</i> (L.) Brongn.	.	.	0.9	.	10.3	0.1	.	.
<i>Deeringia polysperma</i> (Roxb.) Mog.	0.6	.	.	0.2	.	0.8	.	.
<i>Lichrostachys microcephala</i> Renvoize	2.3	.	.	0.8	.	.	.	.
<i>Dracaena reflexa</i> Lam. var. <i>angustifolia</i> Baker	1.8	.	.	6.0	.	0.1	.	.
<i>Erythroxylon acranthum</i> Hemsley	1.3	.	.	2.4	0.4	1.4	0.4	0.7
<i>Euphorbia pyrifolia</i> Lam.	3.0	.	4.8	7.1	10.8	0.9	1.1	.
<i>Ficus avi-avi</i> Bl.	0.1	.	.	1.2	0.4	0.2	.	.
<i>Ficus nautarum</i> Baker	0.1	.	0.1	0.2	.	0.6	.	3.3
<i>Ficus reflexa</i> Thunb.	1.6	.	.	1.2	0.7	0.3	0.2	0.1
<i>Flacourtia ramontchii</i> L'Her. var. <i>renvoizei</i> Fosb.	.	.	.	.	.	2.9	4.9	2.3
<i>Guettarda speciosa</i> L.	.	.	.	0.5	4.8	6.5	.	3.7
<i>Grewia salicifolia</i> Schinz	.	.	.	.	.	0.1	.	.

Appendix (continued)

	<u>A1</u>	<u>A2</u>	<u>A3</u>	<u>B1</u>	<u>B2</u>	<u>C1</u>	<u>C2</u>	<u>C3</u>
<i>Jasminum elegans</i> Knobl.								
<i>Lumnitzera racemosa</i> Willd. var. <i>racemosa</i>	0.7	.	.	2.1	0.1	0.1	0.7	.
<i>Maerua triphylla</i> A. Rich. var. <i>pubescens</i>	.	.	.	.	.	.	.	5.3
(Klotzsch) De Wolf								.
<i>Malleastrum leroyi</i> Fosberg	.	.	.	.	.	0.1	0.1	.
<i>Margaritaria anomala</i> (Baill.) Fosb. var. <i>chelonophorbe</i> (Hutch.) Fosb.	.	.	.	.	0.4	.	.	.
<i>Maytenus senegalensis</i> (Lam.) Exell	8.1	0.5	0.2	14.7	11.1	15.9	4.5	1.2
<i>Mystroxydon aethiopicum</i> (Thunb.) Loes.	17.7	0.5	.	21.6	4.1	16.0	8.7	2.0
<i>Operculicarya gummifera</i> (Srague) Capuron	.	.	.	.	0.1	.	2.0	.
<i>Ochna ciliata</i> Lam.	0.9	.	0.1	3.2	2.4	7.0	15.1	8.4
<i>Pandanus tectorius</i> Park.	.	.	0.1	0.2	.	2.3	0.2	6.4
<i>Paretta verdcourtiana</i> Fosb.	1.0	.	0.1	0.6	.	0.1	0.1	.
<i>Pemphis acidula</i> Forst.	9.4	.	4.9	12.6	.	2.3	.	.
<i>Phyllanthus casticum</i> Soy. Will.	0.9	.	.	.	.	0.3	.	.
<i>Plumbago aphylla</i> Bojer ex Boiss.	.	15.0	27.9	0.6	0.1	.	.	.
<i>Polysphaeria multiflora</i> Hiern	8.8	.	0.2	8.2	9.8	13.9	22.7	2.6
<i>Premna obtusifolia</i> R.Br.	.	.	.	0.1	.	.	.	.
<i>Scaevola taccada</i> (Gaertn.) Roxb.	1.8	.	15.6	0.2	2.5	0.5	.	.
<i>Scutia myrtina</i> (Burm.f.) Kurz	0.8	.	.	0.2	0.1	0.2	.	.
<i>Sideroxylon inerme</i> L.ssp. <i>cryptophlebium</i> (Baker) Hemsl.	9.9	1.3	.	10.1	4.3	3.0	0.1	0.3
<i>Solanum indicum</i> L. var. <i>aldabrense</i> (C.H. Wright) Fosb.	0.2	.	.	0.4	0.4	0.4	.	0.1
<i>Sophora tomentosa</i> L.	0.3	.	.	.	.	.	.	.
<i>Stachytarpheta jamaicensis</i> (L.) Vahl	.	.	5.3	.	1.2	.	.	.
<i>Tarennia supra-axillaris</i> (Hemsl.) Bremek.	5.9	3.0	.	19.3	1.1	0.9	.	.
<i>Tarennia tricantha</i> (Baker) Bremek.	2.1	3.0	0.1	0.8	4.1	3.0	1.7	0.4

Appendix (continued)

	<u>A1</u>	<u>A2</u>	<u>A3</u>	<u>B1</u>	<u>B2</u>	<u>C1</u>	<u>C2</u>	<u>C3</u>
<i>Terminalia boivinii</i> Tul.	6.3	.	.	17.5	.	1.4	5.6	1.1
<i>Thespesia populnea</i> (L.) Sol. ex Correa	2.9	.	.	.	.	.	.	.
<i>Thespesia populneoides</i> (Roxb.) Kostel	.	.	.	.	.	0.2	0.4	10.4
<i>Tournefortia argentea</i> L.f.	.	.	2.7	0.6	0.1	.	.	.
<i>Triainolepis fryeri</i> (Hemsl.) Bremek.	0.3	.	.	0.1	.	.	0.3	.
<i>Tricalysia sonderiana</i> Hiern	6.8	7.5	.	2.7	0.3	0.2	3.4	.
<i>Vernonia grandis</i> (DC.) H. Humb.	.	.	.	.	0.4	.	.	.
Subclass C4:								
<i>Calophyllum inophyllum</i> L. var. <i>takamaka</i> Fosb.								86.7
<i>Canthium bibracteatum</i>								5.0
<i>Flacourtia ramontchii</i>								5.7
<i>Ludia mauritiana</i> Gmel.								5.7
<i>Mystroxydon aethiopicum</i>								13.3
<i>Ochna ciliata</i>								11.7



Fig. 2. Polythetic divisive classification of sixty-one mixed-scrub sites on Aldabra Atoll.

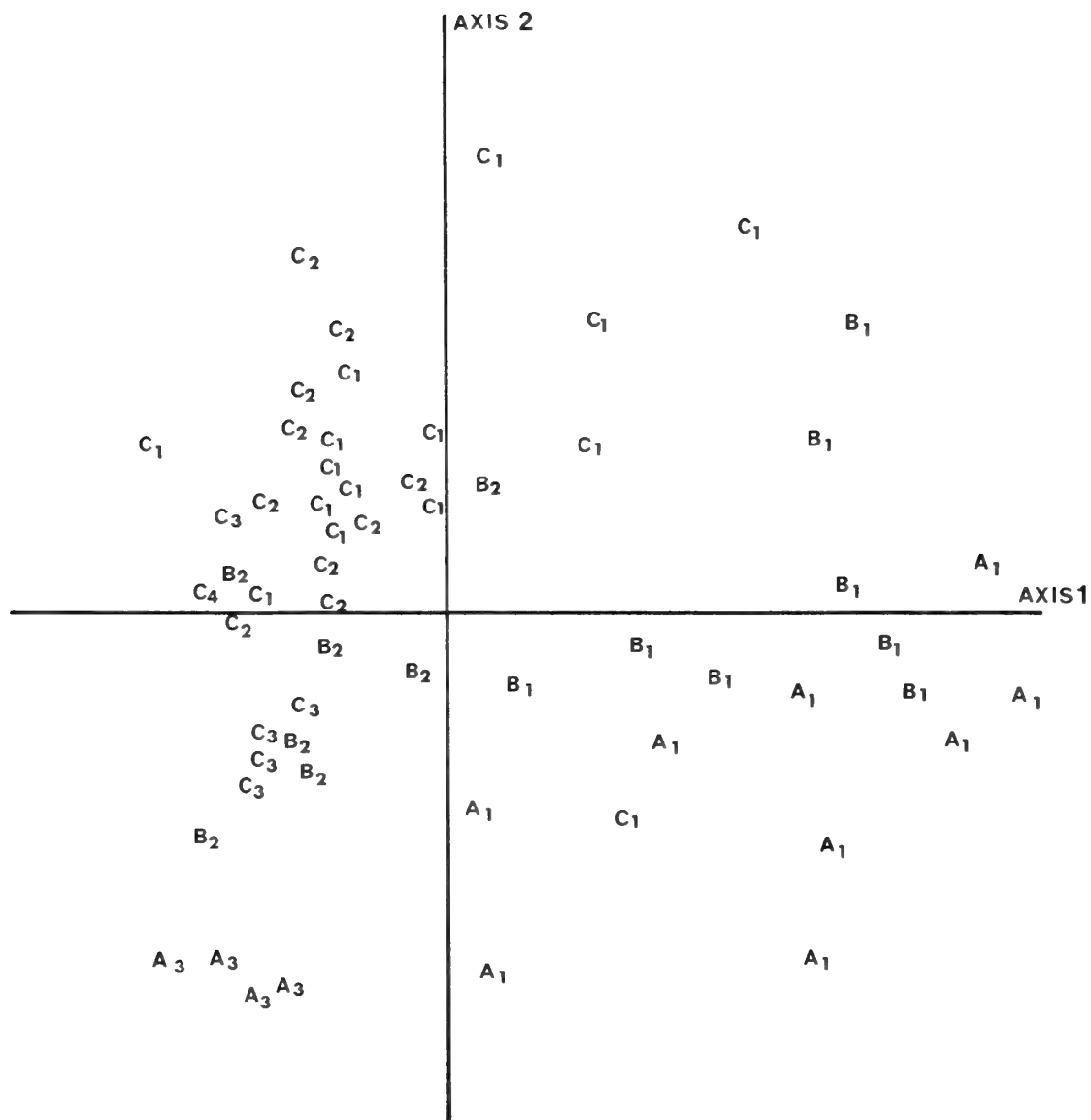


Fig. 3. Principal components ordination of sixty-one mixed-scrub sites on Aldabra Atoll.

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**SPECIES COMPOSITION AND ABUNDANCE OF LAGOON
ZOOPLANKTON AT ENIWETAK ATOLL, MARSHALL
ISLANDS**

by Ray P. Gerber

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ENEWETAK ATOLL
MARSHALL ISLANDS

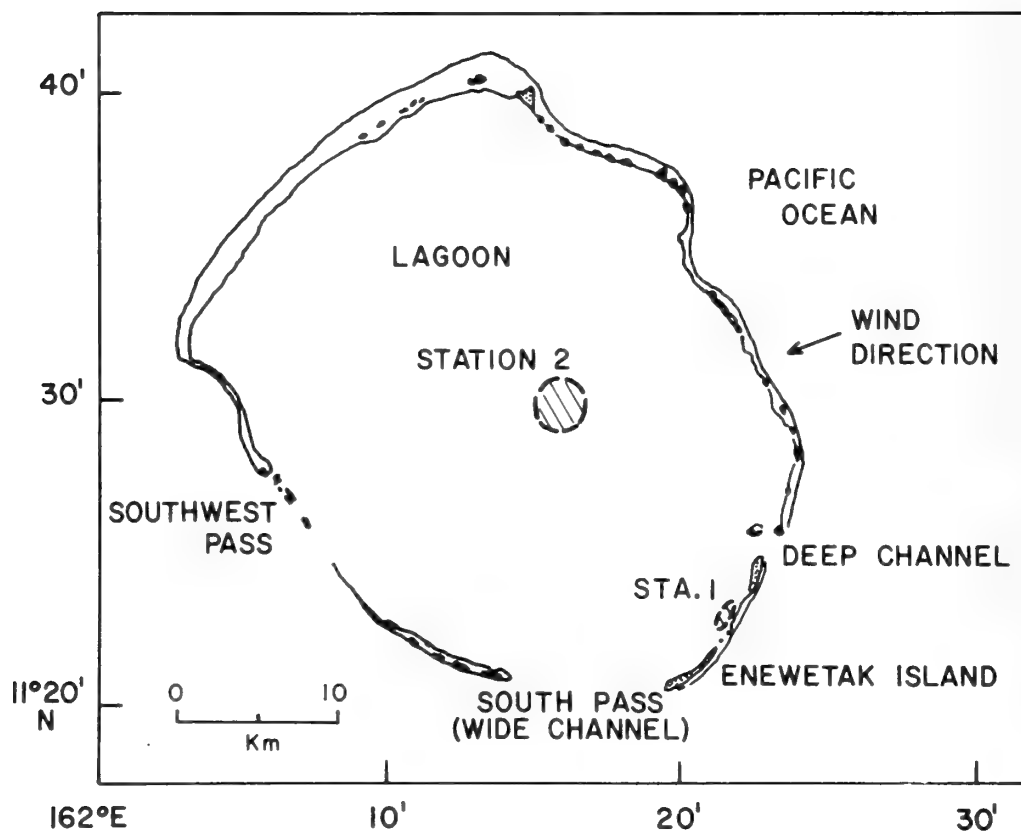


Figure 1. Enewetak Atoll, with sampling stations (1) and (2) indicated

SPECIES COMPOSITION AND ABUNDANCE OF LAGOON ZOOPLANKTON AT ENIWETAK ATOLL, MARSHALL ISLANDS

by Ray P. Gerber¹

ABSTRACT

The species composition and abundance of lagoon zooplankton were studied from net tows made during two winters (January-February, 1972; 1974) and one summer (June-August, 1974) at a mid-lagoon station, and during the winter of 1972 at a shallow back-reef area. About 124 zooplanktonic organisms were identified, which included many species not previously reported from this lagoon.

Copepods, chaetognaths and larvaceans which dominated at the mid-lagoon station were much lower in abundance at the shallow station. At the mid-lagoon station about 56 of the more abundant species increased in abundance during the summer, while 3 species were collected only in the summer; 4 species increased in abundance during the winter, while about 4 species were collected only in the winter; and about 30 species lacked a seasonal preference. The species diversity (Shannon-Wiener and Brillouin indices) of the lagoon zooplankton, which ranged from about 3.8 to 3.9, was not significantly different for the winter and summer populations. This lack of a difference in diversity may be due to certain limitations inherent in such indices when used to describe complex communities.

INTRODUCTION

Kramer (1897) working in the lagoon at Samoa made the first quantitative study showing a greater abundance of plankton in the lagoon than in the surrounding ocean. Though rarely cited, this work was confirmed by subsequent studies of Russell (1934) at the Great Barrier Reef lagoon, Edmondson (1937) in the semienclosed waters around Oahu, Motoda (1938) in the lagoon at Palao, Johnson (1949) at Bikini and nearby atolls including Enewetak, Michel (1969) at Mururoa Atoll, Michel *et al.* (1971) at Rangiroa Atoll, and Tranter and George (1972) at

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Kavaratti and Kalpeni Atolls. Except for the study by Johnson (1949), these investigations were more concerned with the relative abundance of the total plankton or of major taxa rather than species composition. Other publications which identified zooplankton species include a preliminary survey of the more important organisms by Gilmartin (1958) at Enewetak; and studies on lagoon copepods by Mahnken (1966) from Rongelap with two additional samples from Enewetak, and by Barnett (1967) from Enewetak lagoon. Sears (1950) has reported on the siphonophores from this and other atolls in the Marshall Islands. Recently, Sale *et al.* (1976) studied the composition of the zooplankton from the Great Barrier Reef area.

Additional plankton studies have been made in close proximity to the reef and pertained to the role of plankton as an energy source for reef ecosystems (e.g. Glynn, 1973; and Johannes and Gerber, 1974).

The previous lagoon plankton studies at Enewetak were based on samples collected over a few days in one season; Gilmartin (1958) and Barnett (1967) took samples in the winter, and Johnson (1949) and Mahnken (1966) took samples in late summer. Since different collecting methods were used in each of these studies it is difficult to discern seasonal changes in the composition and abundance of the lagoon zooplankton.

In the present work, the lagoon plankton at Enewetak was sampled over longer periods than in the previously cited studies, and included samples from two winters and one summer. Essentially, the same methods were used throughout the study, and all the organisms in each subsample were counted and identified. These data allow consideration of seasonal patterns in the species composition and abundance of the lagoon zooplankton.

METHODS

Two lagoon stations were sampled (Fig. 1) at Enewetak Atoll, Marshall Islands during two winters (Jan.-Feb., 1972 and 1974), and one summer (June-Aug., 1974). Station 1 was located along an interisland reef about 150 m behind the reef crest and was sampled only in the winter of 1972. This station was about 2 m deep and characterized by a slight unidirectional flow of water from in front of the reef during mid to high tides. Station 2 was located about mid-lagoon, 15-20 km northwest of Enewetak Island, in about 50 m of water, and was sampled in all three periods.

Zooplankton was collected with a 1/2 m diameter, #6 mesh Nytex^R net, aperture 0.239 mm, from January 1 - January 29, 1972; and with a 1/2 m diameter, #10 mesh net, aperture 0.158 mm, from January 27 - March 3, 1974 and June 16 - August 7, 1974. Nets were equipped with internally mounted, calibrated, T.S.K. flowmeters. Each sampling consisted of oblique tows, made from about 35-40 m to the surface at Station 2, and from about 1 1/2 m at Station 1 on incoming tides.

Because Station 1 was shallow, it was necessary to make several continuous oblique tows in order to sample roughly equivalent volumes from both stations. Tows were made from about 0930 to about 0230. Station 1 was sampled ten times and only during the winter of 1972, and on the same days as the sampling of Station 2. At Station 2 during the winter of 1974 and summer of 1974 twelve samples were collected each period. All samples were preserved in 5% glutaraldehyde in sea water, kept cool and in the dark. This method of preservation retains pigmentation of the organisms better than formalin, aiding in identification and enumeration. Total volume of water filtered by the nets ranged between 15-22 m³.

The liquid volumes in the zooplankton samples were adjusted to 100 ml, all organisms and debris larger than 4 mm were removed, and the suspended plankton subsampled using a 2 ml Stemple Pipette. Using a dissecting microscope and a gridded counting dish, all the material from five successive subsamples were identified and counted along with the larger organisms initially removed. For this 10 ml subsample the total number of individuals counted ranged from about 300 to 350 for adults, and about twice these values for juveniles and smaller organisms. It was necessary to count such large numbers of organisms since the samples often contained large amounts of mucus-like material which caused clumping of the zooplankton organisms. The presence of one individual in the subsample represented abundances ranging from about 0.5 to 1.4 organisms m⁻³.

Seasonal changes in the lagoon zooplankton populations at the mid-lagoon station were analyzed with regard to species composition and abundance, statistically using ANOVA and Duncan's Multiple Range Test (Steel and Torrie 1960), and calculation of Shannon-Wiener and Brillouin diversity indices (Peet 1974; Pielou 1969).

RESULTS

1. Species composition and station distribution

Some 96 species of copepods, 6 chaetognaths, 7 larvaceans, 9 mysids, 1 euphausiid, 3 amphipods, 8 siphonophores, 2 pteropods, and at least 4 species of dinoflagellates were found in Enewetak lagoon in this study. Several medusae, ostracods, cladocera, isopods and various invertebrate and fish larvae were counted but not identified to species. Seven additional species of planktonic copepods (*Acartia fossae* cf. *A. hamata*, *Calocalanus pavoninus*, *Corycaeus flaccus*, *Corycaeus latus*, *Corycaeus tenuis*, *Eucalanus monachus*, and *Lucicutia ovalis*), twenty species of benthic harpacticoid copepods, plus the rest of the above zooplankton groups, except for the siphonophores, have not been previously reported from this lagoon.

Table 1 presents a summary of the approximate abundance levels in numbers of organisms m⁻³, for the two lagoon stations and for the three sampling periods. The zooplankton from Station 1 (behind-reef) are

characterized by a lower abundance, fewer species of typically planktonic organisms, and a greater number of benthic and meroplanktonic forms such as harpacticoid copepods, mysids, isopods and some larvae, as compared to the mid-lagoon station. Several species of presumably planktonic copepods (*Calocalanus pavoninus*, *Lucicutia ovalis*, *Macrosetella gracilis*, *Monstrilla* sp., *Oithona pseudofrigida* and *Scolecethricella dentata*), as well as a few possible epizooic cyclopoid copepods, were restricted to this shallow station. At the mid-lagoon station the calanoid and cyclopoid copepods predominated in terms of numerical abundance and numbers of species. Most other groups such as the larvaceans, chaetognaths, euphausiids, pteropods, and dinoflagellates were also greater in abundance, while the amphipods and siphonophores were restricted to the mid-lagoon station.

2. Seasonal distribution

Statistical analysis of the zooplankton data at the mid-lagoon station indicated considerable variability between samples collected during the same period (Table 1). Often the standard deviation of the mean is equal to or even exceeds the value of the species' mean abundance. Table 1 indicates that there is almost no difference between the species composition and abundance of the mid-lagoon zooplankton from the two winter sampling periods. Considerable differences are apparent in species composition and abundance of the mid-lagoon zooplankton between the summer and the two winter sampling periods. Fifty-six species, consisting mainly of copepods, were significantly greater in abundance, at the 0.05 probability level, during the summer compared to the previously sampled winter periods; and only 3 species, consisting of the copepods *Corycaeus tenuis* and *Temora discaudata* and one siphonophore *Lensia* sp., appeared to be restricted to the summer. In contrast 4 species of copepods, *Centropages* (copepodites), *Clausocalanus furcatus*, *Euchaeta rimana* and *Undinula* (copepodites), were significantly more abundant in the winter compared to the summer; and 31 species were collected only in winter. Statistical evaluation of these 31 winter species indicated that only 4 were significantly greater than zero, and consisted of the three copepods, *Acartia fossae*, *Acrocalanus* (copepodites), *Candacia catula*, and one dinoflagellate, *Pyrocystis fusiformis*. An additional 30 species or organisms did not exhibit any seasonal changes by statistical evaluation. The majority of the organisms in this group are of low abundance, less than 5 organisms m^{-3} , and therefore does not represent a significant portion of the total population.

3. Species diversity

Table 2 presents the Shannon-Wiener and Brillouin species diversity indices (Peet 1974; Pielou 1969), calculated for each sample collected from mid-lagoon station. The number of species per sample ranged from 56 to 77 in all the samples, while the mean number of species from the different sampling periods ranged between 62-68 species. The Shannon-Wiener and Brillouin diversity indices were very similar and the Kruskal-Wallis one-way ANOVA (Siegel 1956)

indicated that there was no significant difference at the 0.05 probability level between the mean diversity indices for the three sampling periods (d.f.=2; for Shannon indices $H=0.736$, and for Brillouin indices $H=0.655$).

DISCUSSION

A more complete study on the seasonal distribution and abundance of zooplankton from Enewetak lagoon would require a series of samples collected periodically throughout one or more years. Such a study was not the intent of the present work which was confined to the summer and winter periods. These two periods, however, represent the two extremes of the seasonal cycle in terms of wind, rain and lagoon circulation patterns (Barnes *et al.*, 1948; Von Arx 1948; Smith personal communication), and it was initially felt that any seasonal change in the zooplankton population would also be most pronounced during these periods.

The low abundance of holoplanktonic zooplankton and proportionally greater abundance of meroplanktonic form found in this study at Station 1 (behind-reef), is typical of coral reef environments (e.g. Gerber and Marshall 1974, Sale *et al.*, 1976). Avoidance behaviour to this shallow area, as well as predation by the coral reef community are believed to account for this observation (Glynn 1973). Meroplanktonic organisms, such as harpacticoid copepods, in these samples were perhaps inadvertently washed from the reefs, while certain other meroplanktonic forms, such as invertebrate larvae were probably actively released from the reefs in the dispersal process. Undoubtedly these net collections of zooplankton made during the day underestimated the total shallow water zooplankton population. Emery (1968) and Sale *et al.*, (1976) both found extensive zooplankton populations in close proximity to the corals and adjacent sediment, especially at night. But these forms were mainly epibenthic resident types rather than typical open-water holoplanktonic zooplankton, which was of interest here. However, the present study collected several species of typically planktonic copepods which appeared to be restricted to this shallow area. Somehow, these species are capable of maintaining position with respect to the reef and avoid predation.

At Station 2 (mid-lagoon), the greater abundance of zooplankton in these deeper waters is evidence of an environment more apt to promote growth and reproduction of the holoplanktonic species. A deeper water column, lack of intensive predation and better food conditions are all possible explanations. Gerber and Marshall (1974 and in preparation) have found that the major food supply to the lagoon zooplankton consists of detritus exported from the surrounding reef communities. Calculations of the total supply of reef detritus available to the lagoon zooplankton was found to be more than sufficient to meet their metabolic needs.

One criticism in examining and discussing the results of the zooplankton collections from Station 2 (mid-lagoon) concerns the lack of night collections which would possibly reveal additional species,

unable to avoid the towed net, and additional vertically migrating species missed because of sampling depth, as well as greater overall abundance. In Barnett's (1967) study of the vertical distribution of the copepods at Enewetak lagoon, he found 67 species with perhaps only 3 species which exhibited diel migrations. However, the total number of nonmigrating species were so great that they masked the vertical movements of the migrating species. In the present study about 78 species of planktonic copepods were recorded in the winter, and in abundances comparable to Barnett's winter collection. It is therefore felt that zooplankton collections reported here have adequately sampled the population within the limitations reported earlier

Without detailed information on the circulation patterns of the lagoon waters and the degree of exchange with the outside ocean waters an explanation for the seasonal changes in species composition and abundance of the lagoon zooplankton can only be tentative. Since the annual variation of lagoon water temperature and salinity is slight (about 0.7°C and 0.15 ‰, Barnes et al., 1948), one explanation for the seasonal changes in the lagoon zooplankton may be related to the residence time of the lagoon waters. Based on temperature and salinity measurements in and around Enewetak lagoon, Smith (personal communication) calculated that the summer flushing rate is considerably longer (perhaps on the order of three months) than the winter flushing rate (which may be as short as one month). Minimal dispersal losses of the lagoon zooplankton along with an increase in phytoplankton production (Gerber and Marshall, in preparation) in summer, could account for the increased lagoon zooplankton populations observed in this study.

Most of the copepod species which dominated the zooplankton in the lagoon and increased significantly in abundance during the summer, are also common, though reduced in abundance, in the surrounding waters of the Pacific North Equatorial Current (Scott 1909; Mori 1937; Wilson 1942; Johnson 1949; Chiba et al., 1955; Mahnken 1966). This is not the case for the copepods *Corycaeus tenuis* and *Temora discaudata* which were abundant and completely restricted to the summer lagoon samples. These two copepods occur in the Indo-Pacific area (Dahl 1912; Delsman 1939; Dakin and Colefax 1940) and were possibly introduced into Enewetak lagoon by eastward moving water masses which shift slightly northward in summer (Barnes et al., 1948; Mao and Yoshida 1955). As further evidence of their seasonality, these two copepods were present in the gut contents of several species of plankton feeding fishes collected at Enewetak lagoon in the summer of 1973, but were absent in the same species of fish collected the preceding winter (Gerber, unpublished data).

Despite the increase in abundance of a major portion of the lagoon zooplankton population in summer a significant change in the species diversity (Shannon-Wiener and Brillouin) was not observed. Both indices take into account the total number of species in addition to the dispersion of individual specimens among the given number species,

though the Brillouin index is less sample-size dependant than the Shannon-Wiener index (Patten 1962). If as Peet (1974) argues, such indices are most sensitive to changes in the rarest species rather than in the common species, then the lack of a significant increase in the Shannon-Wiener and Brillouin indices for the summer lagoon zooplankton populations is understandable. Also, Margalef (1968) indicated that for rich tropical phytoplankton communities slight increases in diversity are poorly expressed by these indices since they asymptotically approach a maximum of around 4.5. The diversity indices for the lagoon zooplankton are close to this value, indicating that the lagoon zooplankton population has a very high biotic diversity. By contrast diversity indices fluctuate around 2.5 in coastal populations of temperate marine plankton, and range from 0.8 to 2.2 for adult fresh-water zooplankton (Margalef 1968).

It is concluded from this study that the zooplankton of Enewetak lagoon appear to exhibit an increase in abundance during the summer season. This community has a very high species diversity though a definite change in diversity between the winter and summer populations could not be shown.

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Table 1. Abundance levels of lagoon zooplankton from Enewetak Atoll lagoon.

Mean values are shown (\pm) one standard deviation of the mean. Underscoring of adjacent or separated means indicates no significant difference at the 0.05 probability level (ANOVA and Duncan's Multiple Range Test: Steel and Torrie 1960)

Station 1 Behind Reef	Station 2 Mid-Lagoon			F-values	Species
	Winter 1972	Winter 1972	Summer 1974		
2.3 \pm 1.7	13.4 \pm 10.7	8.5 \pm 8.6	29.5 \pm 14.3	3.68	Calanoid Copepods <i>Acartia negligens</i> Dana, 1894.
5.1 \pm 3.7	14.6 \pm 10.7	8.1 \pm 6.1	-	11.69	<i>A. fossae</i> Gurney, 1927.
1.5 \pm 1.3	10.2 \pm 8.6	6.7 \pm 7.8	21.0 \pm 15.4	4.51	<i>Acartia</i> (copepodites)
0.3 \pm 0.3	2.5 \pm 3.1	1.1 \pm 2.6	10.8 \pm 8.5	8.29	<i>Acrocalanus gibber</i> Giesbrecht, 1888.
-	11.0 \pm 11.6	22.5 \pm 24.0	55.8 \pm 30.3	5.72	<i>A. gracilis</i> Giesbrecht, 1888.
1.0 \pm 1.4	2.7 \pm 4.7	3.0 \pm 5.3	-	2.05	<i>A. longicornis</i> Giesbrecht, 1888.
2.2 \pm 2.1	2.3 \pm 5.3	0.9 \pm 1.7	2.0 \pm 5.1	0.29	<i>A. monachus</i> Giesbrecht, 1888.
3.1 \pm 2.8	7.4 \pm 9.3	16.8 \pm 22.3	-	3.28	<i>Acrocalanus</i> (copepodites)
11.0 \pm 10.1	165.3 \pm 114.4	310.0 \pm 171.7	613.8 \pm 241.6	3.59	<i>Calanopia minor</i> A. Scott, 1902.
-	<0.1	-	-	-	<i>Calanus tenuicornis</i> Dana, 1849.
5.0 \pm 6.6	96.8 \pm 100.2	105.2 \pm 46.6	78.4 \pm 42.2	0.59	<i>Calocalanus pavo</i> (Dana, 1849).
2.3 \pm 1.9	-	-	-	-	<i>C. pavoninus</i> Farran, 1936.
4.8 \pm 6.6	5.3 \pm 5.9	4.0 \pm 5.4	3.3 \pm 4.9	0.50	<i>C. plumulosus</i> (Claus, 1863).
-	12.6 \pm 10.9	14.8 \pm 13.6	38.1 \pm 26.0	4.91	<i>C. styliremus</i> Giesbrecht, 1888.

Table 1. (continued)

Station 1 Behind Reef		Station 2 Mid-Lagoon				F-values	Species
Winter 1972		Winter 1972	Winter 1974	Summer 1974			
2.4 ± 2.9		6.2 ± 8.2	5.1 ± 6.5	3.1 ± 6.1	0.53	Calanoid Copepods (contd.)	
-		<0.1	-	<0.1	0.01	<i>Candacia aethiopica</i> (Dana, 1849).	
-		10.0 ± 11.1	5.3 ± 4.2	-	4.61	<i>C. bispinosus</i> (Claus, 1863).	
-		0.8 ± 1.4	0.7 ± 2.6	-	0.66	<i>C. catula</i> (Giesbrecht, 1889).	
1.8 ± 2.7		4.0 ± 4.1	6.8 ± 5.5	4.7 ± 5.0	0.19	<i>C. truncata</i> (Dana, 1849).	
7.3 ± 7.1		214.4 ± 100.6	344.5 ± 151.7	789.1 ± 528.9	4.58	<i>Candacia</i> (copepodites)	
1.6 ± 2.8		1.4 ± 2.7	1.8 ± 3.4	-	1.21	<i>Canthocalanus pauper</i> (Giesbrecht, 1888).	
-		2.0 ± 3.5	0.5 ± 1.7	-	0.08	<i>Centropages calaninus</i> (Dana, 1849).	
-		2.0 ± 3.4	0.8 ± 2.6	-	0.11	<i>C. elongatus</i> Giesbrecht, 1896.	
0.8 ± 1.9		45.4 ± 30.0	40.9 ± 27.6	55.3 ± 29.6	0.50	<i>C. gracilis</i> (Dana, 1849).	
1.9 ± 2.0		93.5 ± 66.0	109.3 ± 63.4	47.8 ± 31.5	3.70	<i>C. orsinii</i> Giesbrecht, 1889.	
2.0 ± 1.6		54.1 ± 33.5	60.8 ± 53.1	44.0 ± 21.6	0.68	<i>Centropages</i> (Copepodites)	
-		1.8 ± 3.2	<0.1	-	0.63	<i>Clausocalanus arcuicornis</i> (Dana, 1849).	
2.7 ± 2.5		23.0 ± 14.0	10.9 ± 10.8	6.1 ± 7.9	7.88	<i>C. farrani</i> Sewell, 1929.	
1.3 ± 1.4		8.9 ± 9.0	5.3 ± 4.9	6.3 ± 10.2	0.76	<i>C. furcatus</i> Brady, 1883.	
0.5 ± 0.7		14.9 ± 12.6	23.8 ± 37.3	6.4 ± 9.4	1.17	<i>C. pergens</i> Farran, 1926.	
-		<0.1	-	1.4 ± 2.0	0.56	<i>Clausocalanus</i> (Copepodites)	
-		<0.1	-	-	-	<i>Eucalanus attenuata</i> (Dana, 1849).	
						<i>E. monachus</i> Giesbrecht, 1892.	

Table 1 (continued)

Station 1 Behind Reef	Station 2 Mid-Lagoon			F-values	Species
	Winter 1972	Winter 1974	Summer 1974		
-	11.3 ± 16.9	3.0 ± 6.9	1.3 ± 4.6	3.80	Calanoid Copepods (contd.) <i>Euchaeta rimana</i> (Bradford, 1974).
1.3 ± 1.8	-	-	-		<i>Euchaeta</i> (copepodites)
0.9 ± 1.5	11.5 ± 12.4	16.8 ± 16.9	174.3 ± 102.8	3.16	<i>Labidocera laevidentata</i> (Brady, 1883).
3.0 ± 4.16	1.6 ± 3.5	2.0 ± 4.3	-	1.66	<i>Lucicutia flavicornis</i> (Claus, 1863).
<0.1	-	-	-		<i>L. ovalis</i> Wolfenden, 1911.
-	6.5 ± 7.2	9.9 ± 10.1	57.2 ± 30.3	10.87	<i>Mecynocera clausi</i> Thompson, 1888.
2.5 ± 4.4	15.3 ± 21.2	6.9 ± 8.3	173.0 ± 88.3	17.83	<i>Nannocalanus minor</i> (Claus, 1863).
2.9 ± 2.8	531.0 ± 229.6	862.4 ± 582.1	2930.1 ± 1059.9	12.57	<i>Paracalanus parvus</i> (Claus, 1863).
16.7 ± 20.7	1188.2 ± 855.0	3760.5 ± 2597.1	11295.3 ± 4814.1	11.61	<i>Paracalanus</i> (copepodites)
-	<0.1	-	2.6 ± 1.8	3.55	<i>Pleuromamma gracilis</i> (Claus, 1863).
1.6 ± 3.2	0.8 ± 1.4	-	1.9 ± 4.9	0.32	<i>Pontellina plumata</i> (Dana, 1849).
1.1 ± 1.5	-	-	-		<i>Scolecithricella dentata</i> (Giesbrecht, 1892).
-	0.8 ± 1.1	0.9 ± 2.2	-	0.03	<i>Scolecithrix danae</i> (Lubbock, 1856).
-	-	-	138.4 ± 53.5	25.37	<i>Temora discaudata</i> Giesbrecht, 1889.
-	32.3 ± 28.2	20.2 ± 21.5	268.0 ± 206.4	7.95	<i>Tortanus gracilis</i> (Brady, 1883).
<0.1	6.0 ± 5.2	0.8 ± 1.9	1.6 ± 5.4	4.12	<i>Undinula darwinii</i> (Lubbock, 1860).

Table 1 (continued)

Station 1 Behind Reef		Station 2 Mid-Lagoon		F-values	Species
Winter 1972	Winter 1972	Winter 1974	Summer 1974		
<0.1	88.8 ± 42.4	132.7 ± 71.5	205.8 ± 59.7	2.98	Calanoid Copepods (contd.) <i>U. vulgaris</i> (Dana, 1849).
0.7 ± 1.3	274.8 ± 168.7	412.5 ± 271.2	132.9 ± 48.7	4.38	<i>Undinula</i> (copepodites)
					Cyclopoid Copepods
-	2.6 ± 4.2	1.0 ± 2.3	-	1.68	<i>Copilia mirabolis</i> Dana, 1852.
4.1 ± 4.2	11.1 ± 12.0	10.5 ± 10.6	54.3 ± 35.2	8.05	<i>Corycaeus agilis</i> Dana, 1849.
-	0.1	-	-		<i>C. asiaticus</i> F. Dahl, 1894.
2.1 ± 3.7	8.6 ± 6.9	21.3 ± 16.9	85.3 ± 51.5	11.84	<i>C. catus</i> F. Dahl, 1894.
1.4 ± 2.7	2.9 ± 4.2	3.3 ± 4.8	21.8 ± 28.9	3.46	<i>C. crassiusculus</i> Dana, 1849.
-	<0.1	-	<0.1	0.01	<i>C. flaccus</i> Giesbrecht, 1891.
-	1.5 ± 2.5	1.0 ± 2.3	-	0.64	<i>C. latus</i> Dana, 1848.
-	0.6 ± 0.6	0.4 ± 1.4	-	0.28	<i>C. lautus</i> Dana, 1849.
<0.1	<0.1	<0.1	-	0.01	<i>C. limbatus</i> ? Brady, 1883.
-	0.6 ± 1.9	0.8 ± 2.6	-	0.15	<i>C. longistylis</i> Dana, 1849.
9.6 ± 17.4	176.5 ± 111.1	251.3 ± 110.0	585.8 ± 385.8	6.92	<i>C. medius</i> Gurney, 1926.
0.9 ± 1.1	8.8 ± 7.2	6.4 ± 6.7	24.9 ± 18.8	5.26	<i>C. speciosus</i> Dana, 1849.
-	-	-	68.0 ± 47.9	12.86	<i>C. tenuis</i> Giesbrecht, 1891.
-	<0.1	-	-		<i>C. typicus</i> (Kroyer 1849).

Table 1.(continued)

Station 1 Behind Reef	Station 2 Mid-Lagoon			F-values	Species
	Winter 1972	Winter 1972	Summer 1974		
-	0.2 ±	0.6	0.6 ± 2.0	0.37	<i>C. vitreus</i> Dana, 1849.
22.0 ± 26.4	62.0 ±	37.4	186.3 ± 82.4	13.93	<i>Corycaeus</i> & <i>Farranula</i> (copepodites)
3.2 ± 2.9	4.7 ±	4.4	11.3 ± 18.9	5.10	<i>Farranula carinata</i> (Giesbrecht, 1891).
8.8 ± 8.9	19.5 ±	10.6	7.5 ± 8.3	3.88	<i>F. concinna</i> (Dana, 1849).
9.6 ± 6.4	17.9 ±	15.8	13.9 ± 13.4	4.48	<i>F. gibbula</i> (Giesbrecht, 1891).
-	<0.1	-	<0.1	0.02	<i>Lubbochia squillimana</i> Claus, 1863.
7.0 ± 8.1	1148.3 ± 1089.0	3326.3 ± 1810.1	7201.1 ± 2100.1	12.05	<i>Oithona nana</i> (Claus, 1863).
7.9 ± 6.4	17.0 ±	17.6	16.1 ± 13.6	24.87	<i>O. plumifera</i> Baird, 1843.
1.3 ± 2.1	-	-	-		<i>O. pseudofrigida</i> (Giesbrecht, 1902).
2.7 ± 6.7	89.8 ±	74.3	230.1 ± 152.8	16.07	<i>O. rigida</i> Giesbrecht, 1898.
-	16.3 ±	12.3	19.0 ± 13.6	8.17	<i>O. tenuis</i> Rosendorn, 1917.
13.2 ± 9.7	193.6 ± 127.5	756.6 ± 317.6	3368.8 ± 1320.5	17.95	<i>Oithona</i> (copepodites)
6.5 ± 5.2	69.3 ±	41.9	62.8 ± 35.4	2.93	<i>Oncaea media</i> Giesbrecht, 1891.
3.8 ± 4.1	17.3 ±	13.7	16.6 ± 24.1	0.03	<i>O. venusta</i> Philippi, 1843.
1.1 ± 2.2	1.7 ±	2.9	0.4 ± 1.4	0.32	<i>Sapphirina stellata</i> Giesbrecht, 1891.
	0.2 ±	0.6	3.3 ± 7.6	2.13	<i>Saphirella tropica</i> Wolfenden, 1905.

Table 1. (continued)

Station 1 Behind Reef	Station 2 Mid-Lagoon			F-values	Species
	Winter 1972	Winter 1972	Winter 1974		
0.7 ± 1.2	-	-	-		Cyclopoid Copepods (contd.)
					Unknown cyclopoids.
					Harpacticoid Copepods
4.1 ± 4.1	-	-	-		<i>Amphiascopsis cinctus</i> (Claus, 1866).
2.7 ± 4.6	-	-	-		<i>Amphiascus coralicola</i> Sewell, 1940.
5.7 ± 5.1	-	-	-		<i>Amphiascus</i> sp.
4.0 ± 6.0	-	-	-		<i>Clytemnestra rostrata</i> Brady, 1883.
1.6 ± 2.9	-	-	-		<i>C. scutellata</i> Dana, 1849.
1.2 ± 2.1	-	-	-		<i>Dactylopoda</i> sp.
1.9 ± 2.6	-	-	-		<i>Eudactylopus andrewi</i> Sewell, 1940.
0.9 ± 2.2	-	-	-		<i>E. anomala</i> Sewell, 1940.
1.6 ± 2.9	-	-	-		<i>E. fasciatus</i> Sewell, 1940.
1.2 ± 2.1	-	-	-		<i>Eudactylopus</i> sp.
2.3 ± 4.9	-	-	-		<i>Harpacticus</i> spp.
2.7 ± 4.0	-	-	-		<i>Laophonte</i> sp.
1.6 ± 2.9	-	-	-		<i>Longipedia coronata</i> Claus, 1866.
2.2 ± 3.0	-	-	-		<i>L. weberi</i> A. Scott, 1909.
2.7 ± 2.8	-	-	-		<i>Macrosetella gracilis</i> Dana, 1852.

Table 1. (continued)

Station 1 Behind Reef		Station 2 Mid-Lagoon			F-values	Species
Winter 1972	Winter 1972	Winter 1974	Summer 1974			
2.3 ± 3.1	-	-	-			Harpacticoid Copepods (contd.)
						<i>Metamphiascopsis hirsutus</i> (Thompson & A. Scott, 1903).
1.8 ± 1.6	-	-	-			<i>Metis</i> spp.
1.4 ± 2.1	3.0 ± 3.6	18.8 ± 18.7	144.2 ± 150.1	6.47		<i>Microsetella rosea</i> (Dana, 1847).
1.5 ± 2.1	-	-	-			<i>Pelididium</i> spp.
1.1 ± 2.3	-	-	-			<i>Tegestes</i> sp.
2.3 ± 3.2	4.2 ± 4.2	4.0 ± 5.4	9.8 ± 13.1	0.82		Unknown harpacticoids
						Monstrilloid Copepods
1.2 ± 3.1	-	0.5 ± 1.7	-	1.30		<i>Monstrilla</i> sp.
56.0 ± 35.3	1290.7 ± 988.8	1623.9 ± 1085.1	5123.2 ± 1429.4	12.15		Copepod Nauplii
50.9 ± 45.1	1195.6 ± 776.2	1405.6 ± 507.1	4887.1 ± 1667.6	14.09		Copepod Copepodites
7.8 ± 4.6	1.2 ± 3.8	1.4 ± 2.1	0.8 ± 2.6	0.08		Ostracods
0.6 ± 1.4	3.6 ± 5.7	7.5 ± 12.9	0.6 ± 2.0	2.10		Cladocera
						Chaetognaths
-	0.2 ± 0.4	-	-	0.06		<i>Pterosagitta draco</i> Krohn, 1853.
-	-	0.6 ± 0.9	-	0.11		<i>Sagitta bipunctata</i> Quoy and Gaimard, 1827.
4.3 ± 5.2	298.7 ± 169.6	365.0 ± 215.6	2199.8 ± 1022.7	13.23		<i>S. enflata</i> Grassi, 1881.

Table 1. (continued)

Station 1 Behind Reef		Station 2 Mid-Lagoon			F-values	Species
Winter 1972	Winter 1972	Winter 1974	Summer 1974			
1.0 ± 1.7	21.6 ± 19.4	47.2 ± 26.6	90.5 ± 33.9	6.48	Chaetognaths (contd.)	<i>S. neglecta</i> Aida, 1897.
8.5 ± 7.6	10.3 ± 9.5	17.6 ± 25.0	60.8 ± 47.1	4.39		<i>S. regularis</i> Aida, 1897.
-	5.9 ± 6.7	4.1 ± 5.5	3.1 ± 5.9	0.67		<i>S. serratodentata</i> Tokioka, 1936.
8.8 ± 10.1	21.8 ± 11.7	38.9 ± 25.8	160.8 ± 68.4	13.49		<i>Sagitta</i> (juveniles)
					Larvaceans	
3.7 ± 5.1	21.9 ± 17.1	26.7 ± 14.1	148.3 ± 121.3	6.10		<i>Fritillaria</i> spp.
6.3 ± 8.9	89.6 ± 58.4	33.7 ± 20.0	187.1 ± 124.4	5.55		<i>Oikopleura intermedia</i> Lohmann, 1896.
-	2.3 ± 3.4	2.2 ± 1.8	-	0.47		<i>O. fusiformis</i> Fol, 1872.
143.4 ± 127.9	1558.9 ± 1242.5	2098.8 ± 1683.5	5489.7 ± 2462.6	6.52		<i>O. longicaudata</i> (Vogt, 1854).
0.5 ± 0.6	1.7 ± 1.9	-	-	0.81		<i>O. parva</i> Lohmann, 1896.
5.5 ± 6.3	105.8 ± 89.2	98.7 ± 62.8	501.5 ± 245.1	12.27		<i>O. rufescens</i> Fol, 1872.
11.5 ± 14.3	21.8 ± 10.9	34.1 ± 21.0	86.4 ± 29.8	3.72		<i>Oikopleura</i> (juveniles)
					Mysids	
1.7 ± 2.5	0.6 ± 1.3	0.5 ± 1.7	1.3 ± 4.1	0.31		<i>Anchialina grossa</i> Hansen, 1910.
3.9 ± 4.8	4.6 ± 9.9	10.1 ± 15.9	2.8 ± 7.7	1.21		<i>A. typica</i> (Kroyer, 1861).
2.6 ± 3.8	0.2 ± 0.4	0.8 ± 1.6	-	1.02		<i>Gastrosaccus indicus</i> Hansen, 1910.

Table 1. (continued)

Station 1 Behind Reef	Station 2 Mid-Lagoon			F-values	Species
	Winter 1972	Winter 1972	Winter 1974	Summer 1974	
					Mysids (contd.)
3.6 ± 6.8	-	-	-	-	<i>G. pacificus</i> Hansen, 1912.
0.6 ± 1.9	-	-	-	-	<i>G. parvus</i> Hansen, 1910.
2.7 ± 5.8	-	-	-	-	<i>Gastrosaccus</i> sp.
10.8 ± 22.9	-	-	-	-	<i>Metamblyopsis</i> sp.
1.7 ± 2.9	-	-	-	-	<i>Pseudanchialina inermis</i> Illig., 1906.
2.9 ± 4.6	-	-	-	-	Unknown Mysids.
					Euphausiids
12.6 ± 25.3	82.9 ± 112.4	48.5 ± 45.8	18.3 ± 15.9	2.49	<i>Pseudeuphausia latifrons</i> (Sears, 1885)
3.4 ± 3.8	28.6 ± 40.2	28.9 ± 60.4	38.4 ± 38.1	0.01	<i>P. latifrons</i> (juveniles)
					Amphipods
-	0.2 ± 0.5	0.6 ± 1.2	-	1.24	<i>Hyperia dysschistus</i> Stebbing, 1888.
-	8.8 ± 3.7	26.3 ± 26.7	63.1 ± 33.7	10.29	<i>H. hydrocephalia</i> Vosseler, 1901.
-	2.3 ± 6.6	2.4 ± 3.4	-	1.11	<i>Synopia ultramarina</i> Dana, 1849.
9.7 ± 13.7	-	-	-	-	Isopods

Table 1. (continued)

Station 1 Behind Reef	Station 2 Mid-Lagoon			F-values	Species
	Winter 1972	Winter 1972	Winter 1974		
-	0.6 ± 1.3	1.1 ± 2.5	2.3 ± 5.8	0.22	Siphonophores <i>Abylopsis tetragona</i> Otto, 1823.
0.1 ± 0.2	0.1 ± 0.1	2.5 ± 3.3	8.3 ± 7.8	2.91	<i>Bassia bassensis</i> Quoy and Gaimard, 1834.
-	0.1 ± 0.1	0.1 ± 0.3	-	0.09	<i>Chelophytes contorta</i> Lens and Van Riemsdijk, 1908.
-	0.3 ± 0.3	-	0.2 ± 0.3	0.06	<i>Diphyes chamissonis</i> Huxley, 1858.
0.3 ± 0.9	2.8 ± 4.9	1.7 ± 2.5	5.0 ± 11.0	0.78	<i>D. dispar</i> Chamisso and Eysenhardt, 1821.
-	0.2 ± 0.6	1.6 ± 3.7	3.8 ± 7.7	1.37	<i>Lensia subtilis</i> Chun, 1885.
-	<0.1	-	-		<i>L. subtiloides</i> Lens and Van Riemsdijk, 1908.
-	-	-	4.4 ± 3.1	12.17	<i>Lensia</i> sp.
-	0.2 ± 0.2	0.7 ± 2.3	2.0 ± 2.7	0.93	Ctenophores
1.7 ± 0.4	12.9 ± 10.5	22.8 ± 18.5	98.8 ± 72.9	9.52	Medusae
					Pteropods
3.4 ± 5.3	22.6 ± 14.2	77.2 ± 29.4	1879.3 ± 1834.4	9.57	<i>Creseis acicula</i> Rang, 1828.
1.9 ± 1.6	2.9 ± 1.4	3.2 ± 3.0	14.1 ± 5.3	3.53	<i>Limacina</i> sp.

Table 1. (continued)

Station 1 Behind Reef		Station 2 Mid-Lagoon			F-values	Species
Winter 1972	Winter 1972	Winter 1974	Summer 1974			
63.1 ± 76.7	39.5 ± 20.8	58.3 ± 31.2	211.4 ± 84.7	13.51	Larvae	Brachyura zoea
3.2 ± 6.4	1.4 ± 1.3	2.3 ± 4.4	3.1 ± 4.6	0.95		Brachyura megalopa
28.6 ± 39.5	77.0 ± 58.5	137.1 ± 83.8	357.5 ± 70.4	12.01		Decapod larvae
10.2 ± 11.7	11.1 ± 12.2	20.4 ± 14.1	9.3 ± 8.7	1.94		Echinopluteus
89.8 ± 56.5	17.5 ± 19.5	27.1 ± 24.8	43.6 ± 26.6	1.45		Fish eggs
11.9 ± 25.4	20.0 ± 13.3	7.2 ± 9.8	70.7 ± 33.2	12.16		Fish larvae
3.8 ± 4.7	0.2 ± 0.4	3.1 ± 2.6	13.4 ± 5.7	4.22		Gastropod larvae
2.9 ± 3.7	9.1 ± 16.6	5.9 ± 6.8	67.9 ± 57.5	7.53		Polychaete larvae
5.3 ± 5.5	-	-	-			Sponge gemmules
						Dinoflagellates
31.4 ± 21.1	54.5 ± 31.7	135.3 ± 75.2	993.2 ± 484.9	20.90		Ceratium spp.
-	<0.1	0.1 ± 0.2	<0.1	0.45		Dissodinium lunula (Schutt) Taylor, 1972.
3.0 ± 3.0	1.9 ± 2.7	4.0 ± 5.2	-	4.06		Pyrocystis fusiformis Thompson ex Murray, 1876.
46.0 ± 27.3	41.0 ± 24.5	154.2 ± 55.3	429.3 ± 160.4	16.88		P. pseudonociluca Thompson ex Murray, 1876.

Table 2. The number of species and species diversity indices (Shannon and Brillouin) for each zooplankton sample from the mid-lagoon, Station 2, at Enewetak Atoll.

WINTER 1972				WINTER 1974				SUMMER 1974			
DATE	NO. OF SPECIES	SHANN. H	BRILL. H	DATE	NO. OF SPECIES	SHANN. H	BRILL. H	DATE	NO. OF SPECIES	SHANN. H	BRILL. H
1/01	66	3.814	3.781	1/27	64	4.070	4.032	6/16	62	3.867	3.827
1/05	71	3.871	3.834	1/30	61	3.751	3.710	6/20	60	3.951	3.910
1/06	77	4.169	4.133	2/02	62	4.252	4.219	6/23	65	4.028	3.988
1/08	66	3.487	3.452	2/04	65	3.976	3.939	6/28	69	4.003	3.962
1/10	68	3.735	3.705	2/06	65	3.544	3.504	7/01	60	3.698	3.662
1/13	63	4.195	4.158	2/09	58	3.813	3.779	7/05	62	4.153	4.111
1/15	66	3.775	3.742	2/12	75	3.850	3.810	7/13	62	3.919	3.885
1/23	69	3.595	3.561	2/16	59	3.806	3.769	7/18	57	4.196	4.154
1/27	66	3.937	3.903	2/22	60	3.216	3.178	7/24	63	3.943	3.901
1/29	71	4.213	4.178	2/25	66	4.130	4.094	7/28	60	3.652	3.614
				2/27	56	3.325	3.289	8/02	59	3.770	3.733
				3/01	60	3.886	3.851	8/07	56	3.826	3.787
$\bar{X} \pm$	68.3 \pm	3.879 \pm	3.845 \pm		62.6 \pm	3.801 \pm	3.765 \pm		62.0 \pm	3.917 \pm	3.878 \pm
S_x	3.8	0.249	0.250		4.8	0.311	0.311		3.1	0.166	0.162

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**THE BIRDS OF ASSUMPTION ISLAND, INDIAN OCEAN:
PAST AND FUTURE**

by R. P. Prÿs-Jones, M. S. Prÿs-Jones, and J. C. Lawley

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THE BIRDS OF ASSUMPTION ISLAND, INDIAN OCEAN: PAST AND FUTURE

by R. P. Prÿs-Jones, M. S. Prÿs-Jones, and J. C. Lawley¹

INTRODUCTION

Assumption (9°43'S 46°30'E) is a small kidney-shaped island of c. 10.5 km² which forms part of the Aldabra archipelago, lying just south of the equator in the western Indian Ocean. Maps showing both the position of the archipelago relative to other land masses in the region, and also the relative positions of the islands and atolls comprising the archipelago, are given in Stoddart (1971). Despite being the closest neighbour of the large and well-studied Aldabra atoll, which is 27 km to the north-west, few people have recorded information on the birds of Assumption, and none who did was present there for more than a few days (Table 1). What little is known of the general ecology of the island has been largely summarized in a paper by Stoddart *et al.* (1970) which catalogues the massive human disturbance which the Assumption environment has suffered during the present century, principally as a result of phosphate mining. Their paper contains a detailed map of the island as well as numerous photographs taken during the late 1960s, and collates most records of birds made prior to 1977. Limited additional information may be found in Parker (1970) and Stoddart (1977a, 1977b).

The aim of the present paper is three-fold: firstly, to up-date knowledge of the status of the Assumption avifauna, based on trips we made to this island in 1977 and 1978; secondly, on the basis of all available published and unpublished records, to describe the original avifauna and document the time-scale and likely causes of its destruction; thirdly, to consider future conservation of the Assumption Island environment in the light of recent introductions of a number of exotic bird species.

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Table 1. Main sources of information on the birds of Assumption.

<u>Date of visit</u>	<u>Bird observers</u>	<u>Main references</u>
Oct. 1878	F. Rivers	Rivers (1878)
Sept. 1892	W.L. Abbott	Ridgway (1895)
8-10 Nov. 1895	S.C.E. Baty	Baty (1895)
13 Oct. 1901	H. A'C. Bergne	Bergne (1901)
12-13 March 1906	M.J. Nicoll	Nicoll (1906, 1908)
19-21 Sept. 1906	P.R. Dupont	Dupont (1907)
April/May 1907	H.P. Thomasset	Thomasset (1907)
6-13 Sept. 1908	J.C.F. Fryer	Fryer (1911)
1916	P.R. Dupont	Dupont (1916)
4 Oct. 1929	P.R. Dupont	Dupont (1929)
c. Oct. 1937	L.D.E.F. Vesey-FitzGerald	Vesey-FitzGerald (1940, 1941)
13 Dec. 1957	W.D. Hartman	Hartman (1958)
10 Oct. 1964	J.W. Leech, R. Worrell, R.W. Thomas	Bourne (1966)
10 Nov. 1964	M.J. & M. Penny, R. Gaymer	Stoddart et al (1970)
3 Oct. 1965	R. Gaymer	"
15-16 Sept. 1967	C.W. Benson, J.M. Boyd, J.F. Peake, E.N. Wright	"
8 Oct. 1967	I.S.C. Parker	Parker (1970)
31 July 1968	J. Frazier, R. Hughes	Stoddart et al (1970)
18-25 April 1977	M. Walker	This paper
26 Oct. - 2 Nov. 1978	J. Lawley	Lawley (1979) & this paper

N.B. List revised and up-dated from that in Stoddart et al (1970).

METHODS

Marilyn Prÿs-Jones (M.P-J.) visited Assumption between 18 and 25 April 1977, and recorded information on birds at the request of R. Prÿs-Jones (R.P-J.) who was then studying the birds on Aldabra Atoll. Although primarily interested in Lepidoptera, M.P-J. had more than a year's experience of bird watching on Aldabra, and took notes and sketches of those species of whose identity she was uncertain. During her visit she thoroughly covered the whole area of the island, spending each day in the field.

J. Lawley (J.L.) visited Assumption between 26 October and 2 November 1978 specifically to study the birds. During his stay he covered most of the island, although concentrating on the coastal area, as well as circling the island once by boat and making almost daily fishing trips in the early morning or late evening. He spent one night camped ashore on the south-west coast.

R.P-J. was responsible for the collation of the information obtained by M.P-J. and J.L., and for the writing of this paper. The species section, immediately following, includes all relevant information on birds recorded by either observer; where not otherwise specified by their initials, similar sightings were obtained by both. A complete listing of the known past and present status of all bird species recorded from Assumption Island, other than domestic chickens and ducks, is given in Table 2. Mr. Hector Paturau, who is referred to frequently below, was the phosphate mining company representative for Assumption until his recent death.

RESULTS AND DISCUSSION

Species Recorded in 1977/78Red-tailed Tropicbird *Phaethon rubricauda*

M.P-J. recorded several flying over the island, and J.L. saw one. The only previous records were made over seventy years ago by Abbott (Ridgway 1895), who found it breeding, and Nicoll (1906).

White-tailed Tropicbird *Phaethon lepturus*

M.P-J. saw one individual flying over the island, and found an adult with a tiny chick in a crevice under a bush at the north end of the island on 25/4/77. J.L. found a single pair which we saw going in and out of a hole in cliffs on the south-west coast on 30/10 and 1/11/78, apparently nesting. These represent the first records for this species from Assumption, although it breeds commonly on Aldabra (Diamond 1971).

Table 2. Bird species recorded from Assumption Island, and their present status.

Species	Status	Recorded by	
		M.W.	J.L.
Red-tailed Tropicbird <i>Phaethon rubricauda</i>	(B), C	+	+
White-tailed Tropicbird <i>Phaethon lepturus</i>	B	+	+
Red-footed Booby <i>Sula sula</i>	(B), C	+	+
Masked Booby <i>Sula dactylatra</i>	(B), C		
Abbott's Booby <i>Sula abbotti</i>	(B)		
Greater Frigatebird <i>Fregata minor</i>	C	+	+
Lesser Frigatebird <i>Fregata ariel</i>	C	+	+
Green Heron <i>Butorides striatus</i>	B?	+	+
Squacco Heron sp. <i>Ardeola idae/ralloides</i>	C		
Cattle Egret <i>Bubulcus ibis</i>	C	+	+
Little Egret <i>Egretta garzetta</i>	C		
Grey Heron <i>Ardea cinerea</i>	B?	+	+
White-faced Tree Duck <i>Dendrocygna viduata</i>	C	+	
Malagasy Kestrel <i>Falco newtoni</i>	C	+	
White-throated Rail <i>Dryolimnas cuvieri</i>	(B)		
Crab Plover <i>Dromas ardeola</i>	C	+	+
Greater Sand Plover <i>Charadrius leschenaultii</i>	C		+
Grey Plover <i>Pluvialis squatarola</i>	C		+
Sanderling <i>Calidris alba</i>	C	+	+
Little Stint <i>Calidris minuta</i>	C		
Curlew Sandpiper <i>Calidris ferruginea</i>	C	+	+
Whimbrel <i>Numenius phaeopus</i>	C	+	+
Curlew <i>Numenius arquata</i>	C		

	Status	Recorded by	
		M.W.	J.L.
Greenshank <i>Tringa nebularia</i>	C	+	+
Common Sandpiper <i>Actitis hypoleucos</i>	C		
Turnstone <i>Arenaria interpres</i>	C	+	+
Great Crested Tern <i>Sterna bergii</i>	C	+	
Black-naped Tern <i>Sterna sumatrana</i>	C		
Sooty Tern <i>Sterna fuscata</i>	C		
Little Tern <i>Sterna albifrons</i>	C		
Common Noddy <i>Anous stolidus</i>	C		+
Fairy Tern <i>Gygis alba</i>	B?	+	+
Malagasy Turtle Dove <i>Streptopelia picturata</i>	(B), C	+	
Barred Ground Dove <i>Geopelia striata</i>	I, B	+	+
Grey-headed Lovebird <i>Agapornis cana</i>	(I)	+	
Malagasy Coucal <i>Centropus toulou</i>	(B)		
Swift sp. <i>Apus apus/barbatus</i>	C		+
Swallow sp. <i>Hirundo rustica</i>	C		
Red-whiskered Bulbul <i>Pycnonotus jocosus</i>	(I)?	+	
Malagasy Bulbul <i>Hypsipetes madagascariensis</i>	(B?)		
Pied Crow <i>Corvus albus</i>	B	+	+
Souimanga Sunbird <i>Nectarinia sovimanga</i>	B	+	+
Red-headed Forest Fody <i>Foudia eminentissima</i>	(B?)		
Malagasy Fody <i>Foudia madagascariensis</i>	(I)	+	
Common Waxbill <i>Estrilda astrild</i>	(I)	+	
Mozambique Serin <i>Serinus mozambicus</i>	(I)	+	

Key to symbols: B - breeds; (B) - formerly bred; C - casual visitor or migrant; I - introduced; (I) - apparently failed introduction.

N.B. i) The "*Sula leucogaster*" recorded for Assumption by Fryer (1911) was almost certainly not the species now known by this name, i.e. the Brown Booby, but instead a misnomer for the Red-footed and/or Masked Boobies (Gibson-Hill 1950, Stoddart 1977b). Brown Boobies are, however, known as vagrants from Aldabra (Diamond 1971), and may well be added to the Assumption list by future observers. It is often difficult to be sure which species of booby is being referred to in the older reports, and further analysis of such records might be worthwhile.

ii) Contrary to the statement of Watson et al (1963), there appears to be no definite record of the Malagasy White-eye *Zosterops maderaspatana* from Assumption. However, Baty (1895) implies the presence of a "tectec", which might be referable to this species (cf. Dupont 1907).

iii) Thomasset (1907) records that "Rabbits, guinea fowl and chickens have been placed on Assumption.....and appear to be thriving." Other observers fail to mention either rabbits or guinea fowl, and it is unclear if Thomasset's records are based on personal observation or hearsay evidence.

Red-footed Booby *Sula sula*

Seen in some numbers both flying over and feeding offshore. Flock of c. 70-80 observed at rest on the sea by J.L. Formerly bred on Assumption (Nicoll 1906).

Greater Frigatebird *Fregata minor* and Lesser Frigatebird *F. ariel*

Frigatebirds were frequently recorded flying above the island. Most were not identified further, but both species were definitely noted.

Green Heron *Butorides striatus*

Seen frequently both on the coast and also inland around freshwater pools and sink holes where they appeared to feed. Watson et al (1963) and Penny (1974) list this species as breeding on Assumption, but there appears to be no definite record of this although Bourne (1966) includes a sighting of "what may have been young" of this species.

Cattle Egret *Bubulcus ibis*

Common. Appeared to feed around inland pools. Largest numbers recorded together by both M.P-J. and J.L. were c. 70-80 individuals. The species was first recorded on Assumption as recently as 1964, although a flock of 60 was present by 1967 (Stoddart et al 1970).

Grey Heron *Ardea cinerea*

Seen occasionally both on the reef and near inland pools, with a maximum of two or three visible at any one time. One individual seen by J.L. was being harassed in flight by a Pied Crow, and another had been captured by a youth and was destined for the pot. According to the islanders they are resident and apparently breed. The most recent previous record was by Dupont (1907), and breeding has never been confirmed.

White-faced Tree Duck *Dendrocygna viduata*

Three largish, brown, wild ducks with black and white on their heads, which were seen by M.P.-J. on a large pool in scrub behind the Settlement on 24/4/77, must have been this species. On the following day five were present. Not seen by J.L. These represent a first record from Assumption, although the species has previously been recorded as a vagrant on Aldabra (Benson & Penny 1971). The wife of the island manager told M.P.-J. that they were not infrequently seen, and suggested that Mr. Paturau might have introduced them years previously; however, this would seem highly improbable, and he made no mention of having done so.

Malagasy Kestrel *Falco newtoni*

M.P.-J. saw two, possibly three, kestrels flying round the trees of the Settlement area on 21/4/77, of which one was seen to catch and eat a *Phelsuma* gecko. Not seen by J.L. There is no previous record of this species from Assumption, but it is resident on neighbouring Aldabra (Benson & Penny 1971).

Crab Plover *Dromas ardeola*

Quite common. Up to ten seen together along the shore.

Greater Sand Plover *Charadrius leschenaultii*

One seen by J.L. in a shallow rock pool on the shore. Not recorded by M.P.-J.

Grey Plover *Pluvialis squatarola*

One seen by J.L. in a shallow rock pool on the shore. Not recorded by M.P.-J.

Sanderling *Calidris alba*

Several seen along the beaches.

Curlew Sandpiper *Calidris ferruginea*

Two seen by M.P-J. and one by J.L., all towards the southern end of the island. The only previous record is by Parker (1970), although the species is a common migrant to Aldabra (Penny 1971).

Whimbrel *Numenius phaeopus*

Single individual only noted by M.P-J. Seen commonly, either singly or in pairs, along the shore line or a little way inland by J.L.

Greenshank *Tringa nebularia*

Three seen by M.P-J. and a single bird by J.L.

Turnstone *Arenaria interpres*

Commonest shorebird present, occurring frequently in small flocks.

Great Crested Tern *Sterna bergii*

Four, seen by M.P-J. on the beach head on the south-east of the island, flew up and stooped over her before resettling on the same spot. Inspection of the area revealed no signs of nesting. Three other individuals were also seen by M.P-J. flying along the reef edge and then settling on the beach with three Crab Plovers. Not recorded by J.L. The species was listed for Assumption by Dupont (1907), but this is the only previous record although it breeds on Aldabra (Diamond 1971). The field description and sketch made by M.P-J. make unlikely the possibility of confusion with the similar Lesser Crested Tern *S. bengalensis*, which has been recorded as a migrant on Aldabra (Diamond 1971).

Common Noddy *Anous stolidus*

Frequently seen singly or in small groups around the coast by J.L. On 26/10/78 a large flock of c. 200 was present a mile offshore, mixed with a few Fairy Terns. Not recorded by M.P-J. Only previous record was by Dupont (1907) although the species breeds commonly on Aldabra (Diamond 1971).

Fairy Tern *Gygis alba*

Numbers seen on most days by M.P-J. with a maximum at one time of 30 individuals which were perched on flowering sisal; other birds seen in crevices in solution holes may have been breeding. Those recorded by J.L. were mostly singles or pairs just offshore, although he saw a bird flying inland with a beakful of fish. Said to breed by the islanders, and probable breeding recorded previously by Peake (Stoddart et al 1970), but no definitive proof yet available.

Malagasy Turtle Dove *Streptopelia picturata*

Three individuals seen by M.P-J. in the Settlement area on both 21/4 and 23/4/77. Two appeared to comprise a pair, i.e. a bright male and a duller female, and all resembled the Aldabran subspecies in colouration. Not seen by J.L. These sightings represent the first records for Assumption since 1908, when the species was noted by Fryer (1911).

Barred Ground Dove *Geopelia striata*

Restricted to the Settlement area, and not very abundant. M.P-J. saw a maximum of seven birds together, and found a nest containing an adult with two eggs in a *Casuarina* fork on 23/4/77. J.L. estimated that at least a dozen were present in 1978. These are the first records for Assumption, and Mr. Paturau told M.P-J. that he had introduced the species in 1976.

Grey-headed Lovebird *Agapornis cana*

One male, which was seen briefly by M.P-J. on 19/4/77 inland from the Settlement, constitutes the first record of this species for Assumption. The description taken was of a small, green parrot-like bird, with a grey head, which chattered like a Budgerigar. Not seen by J.L.

Swift sp. *Apus apus/barbatus*

On two occasions J.L. saw a black swift flying low along the shore (Lawley 1979). According to the islanders, such "hirondelles" are regular visitors. Not seen by M.P-J.

Red-whiskered Bulbul *Pycnonotus jocosus*

Four individuals were seen by M.P-J. in and around coconut trees north-east of the Settlement on 18/4/77, and two others in the platin area south of the Settlement on 19/4/77. She heard them at other times also, but they proved shy and difficult to find. J.L. did not see any in 1978, but was told by the wife of the island manager that she had recently seen one. These are the first records for Assumption.

Pied Crow *Corvus albus*

Seen predominantly around the Settlement area. Maximum count of 26 birds seen together by M.P-J. on 22/4/77; as three others had been shot by labourers on 20/4/77 this indicates a population size of around 30 individuals. J.L. estimated the total population in 1978 as between 15 and 20 birds.

Souimanga Sunbird *Nectarinia sovimanga*

Common resident throughout the island wherever trees or bushes are present. Seen feeding from *Scaevola* flowers by M.P-J. In April 1977 M.P-J. found old nests in a *Ficus* bush, on houses and down solution holes, but breeding was apparently over. In October/November 1978 J.L. found a nest suspended from a low bush, and observed both the male and female parents visiting the single tiny chick; only the female was seen to remain and brood.

Malagasy Fody *Foudia madagascariensis*

Between 20 and 30 individuals, both males and females, were released by Mr. Paturau in the Settlement on 18/4/77, after having been brought by ship from Mauritius via Mahe. M.P-J. subsequently resighted birds frequently, but always near the Settlement. Not recorded by J.L. in 1978. This is a first record for Assumption.

Common Waxbill *Estrilda astrild*

A single bird, seen by M.P-J. on some maize near the Settlement on 23/4/77, constitutes the first record for Assumption. Not seen by J.L.

Mozambique Serin *Serinus mozambicus*

Between 20 and 30 birds of this species were released by Mr. Paturau along with the fodies on 18/4/77, and form the first records for Assumption. Numbers were seen subsequently by M.P-J., all being near the Settlement except for one observed in scrub at the extreme north of the island on 21/4/77. Not recorded by J.L.

The Destruction of the Original Avifauna

If introduced species are included, a total of 46 birds have been recorded from Assumption (Table 2). Only three of these (the White-tailed Tropicbird, the Barred Ground Dove and the Souimanga Sunbird) are known to breed at the present time. This very depauperate avifauna is a result of extinctions, which can be inferred to have occurred in two main phases: firstly, following the introduction of goats and rats, which probably took place during the second half of the nineteenth century; secondly, following the human settlement of Assumption in June 1908, after which large-scale vegetation clearance and phosphate extraction began, and pests such as dogs and cats were introduced (although cats may possibly have arrived prior to human settlement).

Little evidence is available regarding the scale of the first phase of extinctions as there are no records which are known to antedate the presence of all introduced pests. The considerable phosphate deposits on Assumption are clear evidence that there must once have been large colonies of seabirds present, but observers in the period prior to human settlement record the breeding only of small numbers of four species. These species, three boobies and one tropicbird, are all

large and long-lived, indicating that smaller, and possibly less site-attached, species such as terns, which one might have expected to be present (Diamond 1979), may have rapidly succumbed to the presence of rats and, possibly, cats. Considering land birds, there is good evidence that at least two species not mentioned in the Assumption bird lists given by Stoddart et al (1970) and Stoddart (1977a) may have become extinct before human settlement began. The evidence for this is based on a careful reading of the text of a letter written by F. Rivers, the first of the observers listed in Table 1. This letter, recording a visit made in 1878, contains lists of the birds which Rivers saw on each of the Aldabra group of islands, the islands being discussed in the order in which he visited them, i.e. Astove, Cosmoledo, Assumption, and finally Aldabra itself. For Astove, Rivers states he found the "colibri", "crow", "cardinal", "ralle", "merle" and "Pigeon Hollandais"; for Cosmoledo, he records "The same land birds are found here as at Astove", but that in addition the "toutourelle rouge" was present. For Assumption, Rivers states that "there amongst the land birds the "Pigeon Hollandais" is not found, but the rest is like the other islands", i.e. Astove and Cosmoledo. This implies that besides the sunbird, crow, rail, and turtle dove, all independently recorded from Assumption by subsequent visitors, a "cardinal" (fody) and "merle" (bulbul) were also present in 1878. Rivers appears to have had no special interest in birds but, wherever they can be cross-checked, his statements appear accurate, and he comes across as a careful observer who recognized that the "merle" and "Pigeon Hollandais" of the Aldabra group of islands were different from those of the central Seychelles; by inference the "merle" and "cardinal" of the different islands of the Aldabra group were probably all the same, i.e. the Malagasy Bulbul and the Red-headed Forest Fody respectively. Stoddart (1977a), who did not include either the bulbul or fody in his tables of birds known from either Assumption or Cosmoledo, accepted Rivers' record of a bulbul from Astove, but doubted his record of a fody there on the grounds that Stirling (1843) failed to mention one. However, even ignoring the possibility of natural extinction and recolonization on small islands, negative evidence is tenuous, as exemplified by Rivers' own failure to record the Malagasy Coucal on Assumption or the Malagasy White-eye *Zosterops maderaspatana* on Astove or Cosmoledo.

The second phase of extinctions is better, but still inadequately, documented. Most species which formerly bred on Assumption but no longer do so appear to have disappeared very rapidly following human settlement (Dupont 1916, 1929), presumably through a combination of habitat destruction and direct predation by man and introduced animals. One definite exception is the Masked Booby which Vesey-FitzGerald (1941) found still to nest in 1937, although he considered that "it is doubtful if young are ever reared here in these days, since labourers in the guano fields destroy both eggs and parent birds". The single Malagasy Coucal also seen in 1937 by Vesey-FitzGerald (1940) may conceivably have been a vagrant from Aldabra rather than a remnant of the original Assumption breeding population. Of particular interest in view of the worldwide rarity of the species is the fate of the Assumption population of Abbott's Booby doubts as to the existence of which have been discounted by a systematic review of available

information (Stoddart 1977b). Second-hand information related to Betts (1940) suggested that adults may have continued breeding attempts until 1930 and not have entirely disappeared until 1936, but Vesey-FitzGerald (1941), who heard that the last one had vanished by 1926, seems likely to be a more reliable source in view of his presence on Assumption in 1937.

The Origins of Recent Arrivals

Ten of the species seen by us comprise new records for Assumption Island. Of these, two, the White-faced Tree Duck and the swift, are clearly casual vagrants. A further two, the White-tailed Tropicbird and the Malagasy Kestrel, probably arrived naturally from neighbouring Aldabra where both have breeding populations. Movement from Aldabra to Assumption may well play an important role in maintaining such bird populations as Assumption now possesses. This is particularly true for the various herons and egrets, none of which has definitely been recorded breeding on Assumption, for the Malagasy Turtle Dove and, possibly, for the Pied Crow. The three Malagasy Turtle Doves seen by M.P.-J. were the first records for Assumption for nearly 70 years, but as many individuals of the large Aldabran population are known to undertake daily, long-distance, intra-atoll movements (Benson & Penny 1971, R. Prÿs-Jones unpubl.) it is perhaps not surprising that some might occasionally reach Assumption. Likewise, the last record of nesting by Pied Crows on Assumption was as long ago as 1906 (Nicoll 1906, 1908), but this species is easily capable of crossing the small distance between Aldabra, where they breed, and Assumption. As an illustration of this, a flock of six Pied Crows were seen to fly in from the ocean onto the isolated small island of Astove in 1976, at a time when the minute population of this species recorded there in 1968 by Benson (1970b) had long since disappeared (H. Stickley, pers. comm.).

Two of the remaining six new species for Assumption, the Malagasy Fody and Mozambique Serin, were definitely introduced in 1977, and Mr. Paturau told M.P.-J. that he had released Barred Ground Doves in 1976. It likewise seems almost certain that the Grey-headed Lovebird, Red-whiskered Bulbul and Common Waxbill were introduced by man at some stage between 1968, the year of the last previous visit by ornithologists, and 1976, with the latter year being the most probable. The fodies and serins were definitely brought by ship from Mauritius via Mahe, and Mauritius is the probable origin of the other species also.

Future Conservation

Prior to the releases documented above, the Aldabra archipelago had been remarkably free of avian introductions, with a single sighting of what was probably a Barred Ground Dove on Cosmoledo being the only example on record (Benson 1970a). (The "sourin" seen on Cosmoledo by Bergne (1901), and identified as either a Mozambique Serin (Benson 1970a) or a Malagasy Fody (Benson et al. 1975), was probably in fact either a naturally occurring Malagasy White-eye (Stoddart 1977a) or possibly a female Red-headed Forest Fody.) Although the original

avifauna of Assumption has been largely exterminated, the introduction of exotic species, apparently in contravention of Seychelles law, is extremely disturbing because of the possible consequences of movements by such exotics from Assumption to Aldabra. Aldabra, unusually among large oceanic atolls, has its original avifauna virtually entirely intact. The only species known to have disappeared in historic times, the Barn Owl *Tyto alba*, apparently did so naturally (Benson & Penny 1971), although the endemic Aldabran Brush Warbler *Nesillas aldabranus* is at present on the verge of extinction (Prŷs-Jones 1979). Introduced species may both carry diseases and also pose a direct competitive threat to isolated island communities. In particular, the Malagasy Fody and Red-whiskered Bulbul have ecological counterparts on Aldabra in the Red-headed Forest Fody and the Malagasy Bulbul respectively. Benson & Penny (1971) have previously commented on the desirability of keeping Malagasy Fodies from Aldabra, and Assumption is clearly too close for a species that may possess the ability to colonize across considerable water gaps (Benson et al. 1975). A further worrying possibility if the Malagasy Fody should reach Aldabra is that it will hybridize with the Red-headed Forest Fody. In Madagascar, Benson et al. (1976/77) have shown that *Foudia omissa*, which is often classified as a subspecies of *F. eminentissima* (Moreau 1960, Moreau & Greenway 1962), has begun to hybridize with *F. madagascariensis* in an area where the ranges of these two species have recently been brought into contact as a result of habitat destruction.

The apparent lack of success of all introduced species on Assumption except the Barred Ground Dove is indicative of the present highly degraded nature of the environment there. In addition, there is a continuing human persecution of larger wildlife which may also be partly responsible for vagrant species from Aldabra failing to establish themselves. As evidence of this M.P.-J. witnessed the killing of three Pied Crows and at least 11 Green Turtles *Chelonia mydas* in a single week in 1977, and J.L. recorded the capture of a Grey Heron for food during his week's stay in 1978. It seems probable that the population of only a single bird species, the endemic race of the Souimanga Sunbird, can be considered self-sustaining at present.

The main conservation measures required on Assumption are effective control on human destruction of the natural fauna and flora, effective controls on the importation of further exotic species, the elimination of introduced mammalian pests, and the restoration of natural vegetation cover. With phosphate extraction still continuing such measures will clearly depend on the cooperation of the mining company as well as the interest of the Seychelles government. The introduction of various exotic species indicates a desire among people present on Assumption for a more diverse bird fauna than now exists, but is clearly the wrong way of achieving this. The first requirement is for improvements in the overall condition of the environment, following which consideration could be given to the re-introduction of bird species that are known formerly to have occurred there, in particular elements of the land bird fauna of Aldabra. Under no circumstances, now or in the future, should further species having no historical connection with Assumption be released there.

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MYXOMYCETES OF ALDABRA ATOLL

by Bruce Ing and R. J. Hnatiuk

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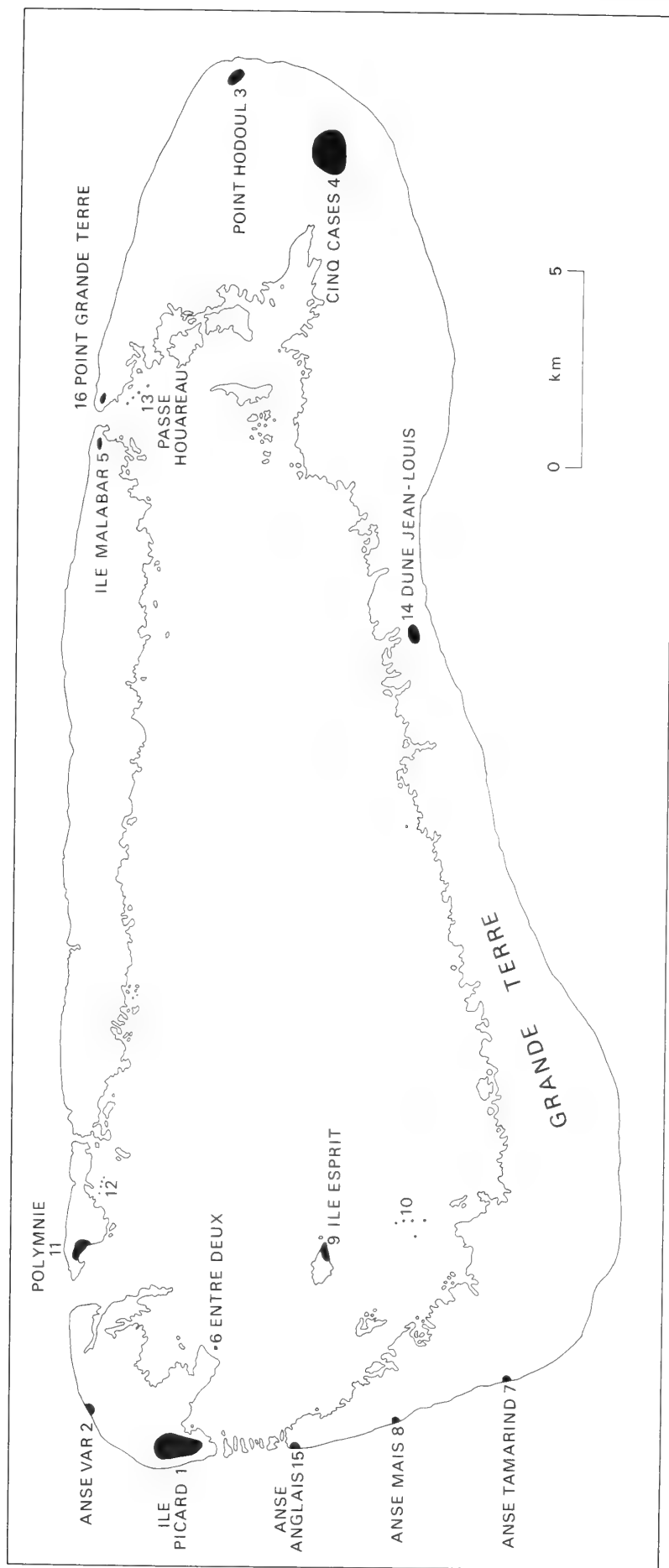


Fig 1. Aldabra Atoll showing the position of the collecting sites.

MYXOMYCETES OF ALDABRA ATOLL

by Bruce Ing¹ and R. J. Hnatiuk²

ABSTRACT

A first list of myxomycetes from the coral atoll of Aldabra in the Indian Ocean is given. 55 species are recorded of which ten are new to the African region. *Didymium floccosum* Martin, Thind & Rehill and *Physarum dictyosporum* Martin are rare species previously known from India and America respectively. Ecological notes are provided, the majority of species occur in litter under scrub, on coconut husks or rotten wood.

INTRODUCTION

Myxomycetes have been recorded infrequently from remote, oceanic islands. Intensive searching of such locations at optimal times of year has not often been possible. The records presented here are some of the most extensive reported from an isolated, tropical island.

Aldabra is a coral atoll in the western Indian Ocean (9°24'S lat., 46°20'E long.) located about 640 km east of Tanzania and 420 km northwest of Madagascar. The atoll consists of an oblong ring of islands around a shallow lagoon. Low calcareous dunes occur at several places around the coast, but in the main the land surface (155 km²) is composed of low-lying limestone which is often rugged, fissured and pitted, but may in some places be flat or undulating sheets and plates. Soil, apart from the coastal sands, is thin and tends to accumulate only in pockets and depressions. The age of the land surface is estimated to be about 80,000 years since the most recent emergence from the sea (Braithwaite *et al.*, 1973). The climate is strongly seasonal: summers are hot and humid while winters are cooler and drier. Most of the annual precipitation (940 mm, Stoddart & Mole, 1977) falls as violent showers from December to April. The cool season receives almost no

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effective rain.

Three major vegetation types dominate the atoll, although many subdivisions are possible (Hnatiuk & Merton, 1979). The low, species-rich shrublands are the most widespread and have only a sparse understorey. Tall woodlands of *Casuarina equisetifolia* and *Cocos nucifera* occur primarily in areas of deep sand along the coast. Grasslands and herblands are found along the coast and in special habitats inland. Litter accumulation is least in most of the grasslands, intermediate in shrubland (but often only in undisturbed places such as pits in limestone where giant tortoises cannot reach), and greatest in woodlands, especially where coconuts accumulate in abandoned plantations.

The most favourable habitats for myxomycetes, in terms of abundance of sporangia, are the old, rotting piles of coconut husks and nuts. The husks hold much water and dry out only slowly, thus providing ideal conditions for extended periods. This is particularly true at the beginning of the dry season when most other habitats have long since dried out. In the grassland, only *Fuligo septica* was found and then only during the main wet season. In shrubland several species in low concentration were found in habitats that ranged from deep, protected leaf litter, to ephemeral litter under seaside scrub, to rotting wood.

COLLECTING SITES

The collections were made by R. Hnatiuk between January and July 1974. The sites are listed under sixteen headings and recorded in the list of species as numbers.

1. Ile Picard. The habitats sampled include groves of *Cocos nucifera* L., in which the piles of rotting husks and other litter were particularly productive; rotten wood and leaf litter in planted *Casuarina equisetifolia* L. woodland; mangrove poles in woodpile; litter in scrub communities composed of various combinations of *Acalypha claoxyloides* Hutch., *Maytenus senegalensis* (Lam.) Exell, *Mystroxyton aethiopicum* (Thunb.) Leosn., *Ochna ciliata* Lam., *Pemphis acidula* Forst., *Sideroxyton inerme* L., *Tarenna supra-axillaris* (Hemsley) Bremek., *Tournefortia argentea* L.f., and *Tricalysia sonderiana* Hiern; litter under *Carica papaya* L. and *Terminalia catappa* L.; on decayed parts of *Agave sisalana* Perrine. In addition collections were made in turf of *Sporobolus virginicus* L. and on moss-covered coral-rock. Nine sets of collections were made between January 24 and July 31.
2. Anse Var. Collections were made near the beach in litter under *Acalypha* and *Maytenus*. (February.)
3. Point Hodoul. Materials were gathered on rotten *Ochna* wood and on litter under dense scrub of *Mystroxyton*, *Sideroxyton* and *Tricalysia* some 40 m from the sea. (February.)

4. Cinq Cases. Several habitats were sampled between the coast and the lagoon, including scrub of *Lumnitzera racemosa* Willd., 800 m inland; dead wood of *Apodytes dimidiata* E. Mey. ex Bernh.; living foliage of *Cyperus* sp., and the remains of *Solanum nigrum* L., as well as scrub of *Mystroxydon* and *Sideroxydon*. (February.)
5. Ile Malabar. Collections from *Tricalysia* litter in a pit in the limestone. (February.)
6. Islet at Entre Deux. Specimens from litter. (February.)
7. Anse Tamarind. Litter under dense coastal *Mystroxydon* scrub. (February.)
8. Anse Mais. The collections were made from Cocos litter in the stand behind the beach. (April and May.)
9. Ile Esprit. A mixture of dense scrub, Cocos husks and litter, dead wood and alga films on coral rock faces. (April.)
10. Islets in the south-west corner of the lagoon, south of Ile Esprit. Mostly covered with *Pemphis* scrub, collections from wood and leaf litter. (April.)
11. Polymnie. Specimens collected on rotten wood. (April.)
12. Islets in the lagoon south of Polymnie. Mostly wood, bark and leaf litter of *Sideroxydon*. (April.)
13. Islets in the lagoon south-east of Passe Houareau. Wood and litter under *Pemphis* and *Sideroxydon* scrub. (April.)
14. Dune Jean Louis. Moss-covered coral rock under scrub and in litter of *Mystroxydon*, about halfway between sea and lagoon. (April.)
15. Anse Anglais. Husks of Cocos in stand behind the beach. (May.)
16. Near Point Grande Terre. On dead wood in stand of *Casuarina*. (June.)

These sites are marked on Fig. 1.

LIST OF SPECIES

Arcyria cinerea (Bull.) Pers.

On husks and other Cocos litter, and on dead wood. 1,8,9,10,12.
(10 gatherings.)

Cosmopolitan. (A,I,M; Mad.)

A. denudata (L.) Wettst.

On Cocos husks. 1. (3 gatherings.)

Cosmopolitan. (A,I,M; Mad, Maur; Marsh.)

- A. incarnata* (Pers.) Pers.
On rotten wood. 9. (1 gathering.)
Cosmopolitan. (A,I,M.)
- Ceratiomyxa fruticulosa* (Müll.) Macbr.
On rotten wood. 9,13. (3 gatherings.)
Cosmopolitan - very common in the tropics. (A,I,M; Mad; Marsh.)
- Clastoderma debaryanum* de Blytt
On *Cocos* husks. 1,8. (5 gatherings.)
Cosmopolitan - very common in the tropics. (I,M.)
- Craterium leucocephalum* (Pers.) Ditm.
On *Mystroxyton* litter. 14. (2 gatherings.)
Cosmopolitan. (A,I,M.)
- Cribraria languescens* Rex
On *Cocos* husks and rotten bark. 8,9. (2 gatherings.)
Probably cosmopolitan but much commoner in the tropics than elsewhere. (A,I.)
- C. microcarpa* (Schrad.) Pers.
On *Cocos* husks. 1. (1 gathering.)
Probably cosmopolitan, common in the tropics. (A,I,M.)
- C. violacea* Rex
On *Cocos* husks and rotten bark. 8,15. (2 gatherings.)
Cosmopolitan. (A,I,M.)
- Diachea bulbillosa* (Berk. & Br.) Lister
On litter under *Mystroxyton*, *Sideroxyton*, *Tournefortia* and *Tricalysia*. 1,3. (2 gatherings.)
Recorded from Central, North and South America, Sri Lanka and eastern Asia.
- D. leucopodia* (Bull.) Rost.
On litter of *Casuarina equisetifolia*, *Lumnitzera*, *Mystroxyton* and *Terminalia catappa*. 1,4. (3 gatherings.)
(A,I,M.)
- D. radiata* G. Lister & Petch
On litter under *Pemphis* and *Tournefortia*. 1. (2 gatherings.)
Recorded from Nigeria, India, Sri Lanka, Thailand, Panama, Chile and Florida.
- Diderma effusum* (Schw.) Morgan
On litter of *Acalypha*, *Maytenus*, *Mystroxyton*, *Pemphis*, *Sideroxyton*, *Tarenna supra-axillaris* and *Tricalysia*. 1,5,10,12,13. (12 gatherings.)
Cosmopolitan. (A,I,M.)

- D. hemisphaericum* (Bull.) Hornem.
On litter, including *Acalypha*. 2,10. (2 gatherings.)
Cosmopolitan. (A,I,M.)
- Didymium anellus* Morgan
On litter under *Sideroxylon*. 13. (1 gathering.)
Recorded from Europe, North America, India, Sri Lanka and the
Phillipines.
- D. eximium* Peck
On litter of *Mystroxyton*. 7. (1 gathering.)
The distribution of this species is uncertain as it is part of the
group of taxa related to *D. nigripes*, recently reviewed by
Nannenga-Bremekamp (1972). It is widely recorded in Europe and
may be cosmopolitan.
- D. floccosum* Martin, Thind & Rehill
On bark litter in coconut grove. 1. (1 gathering.)
This distinctive species was previously known only from the type
locality, in the Mussoorie Hills of northern India (Martin, Thind
& Rehill, 1959) but has now been found in Venezuela (Farr, 1974.)
- D. intermedium* Schroet.
On woody litter and dead *Tricalysia* leaves. 1,4,16. (4 gatherings.)
Recorded from Brazil, Central and North America and Japan, and
considered to be a rare species.
- D. leoninum* Berk. & Br.
On woody litter under scrub. 9. (2 gatherings.)
Recorded from India, Sri Lanka, Singapore, Java, the Philippines,
Japan and, recently, from Jamaica (Farr, 1974.)
- D. melanospermum* (Pers.) Macbr.
On dead branch of *Solanum nigrum*. 4. (1 gathering.)
Cosmopolitan. (A,I,M.)
- D. minus* (Lister) Morgan
On leaf litter of *Maytenus* and *Tricalysia*. 1. (1 gathering.)
Cosmopolitan. (A,I,M.)
- D. nigripes* (Link) Fr.
On leaf litter under dense mixed scrub. 1,3,9. (4 gatherings.)
Cosmopolitan. (A,I,M.)
- D. squamulosum* (Alb. & Schw.) Fr.
On litter of *Cocos*, *Maytenus* and *Sideroxylon*. 1,2,6.
(8 gatherings.)
Cosmopolitan. (A,I,M.)
- D. verrucosporum* Welden
On *Mystroxyton* litter. 4. (1 gathering.)
Recorded from Central and South America and Europe, but probably
widespread.

Fuligo septica (L.) Web.

On rotten *Casuarina* wood, on *Sporobolus* turf and on sedge turf in open coconut grove. 1,8. (4 gatherings.) Cosmopolitan.
(A,I,M; Mad, Maur; Marsh.)

Hemitrichia calyculata (Speg.) Farr (*stipitata* (Mass.) Macbr.)

On *Cocos* husks. 1,8,9. (10 gatherings.)
Cosmopolitan, especially common in the tropics. (A,I,M; Maur; Marsh.)

H. serpula (Scop.) Rost.

On *Cocos* husks. 1. (1 gathering.)
Cosmopolitan, especially common in the tropics. (A,I,M; Mad; Marsh.)

Lycogala epidendrum (L.) Fr.

On *Agave* stump. 1. (1 gathering.)
Cosmopolitan. (A,I,M; Maur.)

Metatrichia vesparium (Batsch) Nann.-Brem.

On *Cocos* husks. 1,8,15. (5 gatherings.)
An essentially North Temperate species, not common in the tropics or the southern hemisphere. (A,I,M; Mad; Marsh.)

Perichaena corticalis (Batsch) Rost.

On very rotten wood. 1. (1 gathering.)
Cosmopolitan. (A,I,M.)

P. depressa Libert

On dead wood. 16. (1 gathering.)
Cosmopolitan. (A,I,M; Mad; Marsh.)

Physarum bogoriense Racib.

On moss on rocks and on litter under *Mystroxydon*, *Sideroxydon* and *Tricalysia* scrub. 1,3,5,9,10,11. (7 gatherings.) Widespread, but especially in the tropics. (A,I,M.)

P. cinereum (Batsch) Pers.

On rotting stem of *Carica papaya*. 1. (1 gathering.)
Cosmopolitan. (A,I,M.)

P. compressum Alb. & Schw.

On rotting *Agave* leaf. 1. (1 gathering.)
Cosmopolitan. (A,I,M.)

P. crateriforme Petch

On algae on steep rock faces. 9. (3 gatherings.)
A widespread species, but nowhere common. (A,I.)

- P. dictyosporum* Martin
On unidentified litter. 12. (1 gathering.)
Known previously only from North America and Costa Rica (Farr, 1976.)
This species has very distinctive spores but superficially resembles the cosmopolitan *Didymium difforme* (Pers.) S.F. Gray, which is not yet known from Aldabra but is reported from Seychelles.
- P. echinosporum* Lister
On litter of *Carica papaya*, *Cocos nucifera*, *Lumnitzera racemosa* and *Terminalia catappa*, and under dense scrub. 1,4,7. (5 gatherings.)
Widespread in the tropics. (A,I,M.)
- P. globuliferum* (Bull.) Pers.
On *Cocos* husks, *Casuarina* logs and mangrove poles. 1,9,16.
(17 gatherings.)
Cosmopolitan. (I,M.)
- P. leucopus* Link
On moss-covered rock under scrub. 1. (1 gathering.)
Cosmopolitan. (A,I,M.)
- P. melleum* (Berk. & Br.) Massee
On litter under dense *Sideroxylon* scrub. 4. (1 gathering.)
Cosmopolitan, especially common in the tropics. (A,I,M.)
- P. mutabile* (Rost.) G. Lister
On living *Cyperus* and leaf litter of *Cyperus*, *Mystroxydon* and *Ochna*. 1,3,4,5. (5 gatherings.)
Scattered throughout the world, generally rare; recorded from South Africa and Sri Lanka.
- P. nicaraguense* Macbr.
On moss-covered rock under scrub, and moss on *Ochna* trunk. 3,14.
(2 gatherings.) Widespread in the tropics, known from West Africa, India and Sri Lanka; also recorded from an atoll in the Caroline Islands.
- P. nutans* Pers.
On wood and husks in *Cocos* grove. 1,8. (2 gatherings.)
Cosmopolitan. (A,I,M.)
- P. oblatum* Macbr.
On *Cocos* litter. 1. (1 gathering.)
Cosmopolitan. (A,I,M.)
- P. pusillum* (Berk. & Curt.) G. Lister
On decaying spathes of *Cocos*. 1. (1 gathering.)
Cosmopolitan. (A,I,M.)
- P. roseum* Berk. & Br.
On *Cocos* husks. 1,8. (3 gatherings.)
An essentially tropical species. (A,I,M.) The Aldabran material approaches *P. pulcherrimum* Berk. & Rav. and strengthens the view that the two taxa are closely related.

P. serpula Morgan

On bark and litter of *Agave*, *Cocos*, *Mystroxydon* and *Sideroxydon*; a collection was also made on the litter in an old nest of a tropic bird (*Phaethron* sp.) 1,9,12,13. (8 gatherings.)
Recorded from Yugoslavia, Central and North America, India and Japan.

P. stellatum (Masse) Martin

On *Cocos* husks, and bark in a pile of mangrove poles. 1.
(5 gatherings.)
Widespread in the tropics. (A,I,M.)

P. tenerum Rex

On *Cocos* husks. 1,8. (3 gatherings.)
Cosmopolitan. (A,I,M; Marsh.)

P. viride (Bull.) Pers.

Very abundant on *Cocos* husks, also on woody litter under *Sideroxydon*.
1,4,8,13. (19 gatherings.)
Cosmopolitan. (A,I,M; Mad; Marsh.)

Stemonitis flavogenita Jahn

On *Cocos* husks and *Ochna* leaf litter. 1. (2 gatherings.)
Probably cosmopolitan but rarely recorded from the tropics. (A,I,M.)

S. fusca Roth

On dead wood, including ?*Apodytes*. 4,10. (2 gatherings.)
Cosmopolitan. (A,I,M; Maur; Marsh.)

S. herbatica Peck

On leaf litter of *Tournefortia argentea*. 1. (2 gatherings.)
Cosmopolitan. (A,I,M.)

S. splendens Rost.

On rotting *Casuarina* log. 1. (1 gathering.)
Cosmopolitan. (A,I,M; Marsh.)

Stemonitopsis typhina (Wiggers) Nann.-Brem. (*Comatricha typhoides* (Bull.) Rost.)

On decaying logs and *Cocos* husks. 1,4,8. (4 gatherings.)
Cosmopolitan. (A,I,M; Marsh.)

All specimens were examined by both authors but the final determinations were the responsibility of B. Ing. Nomenclature follows Martin & Alexopoulos (1969). Voucher specimens for all taxa reported here are deposited in BM and K. The following abbreviations refer to the distribution records: A - reported from the mainland of Africa (various sources); I - reported from India and/or Sri Lanka, formerly Ceylon (various sources); M - reported from the Malesian region (various sources); Mad. - reported from the Malagasy Republic, formerly Madagascar (Patouillard, 1928); Maur. - reported from Mauritius (Wiehe, 1948), and Marsh. - reported from the Marshall Islands, Central Pacific (Rogers, 1947).

DISCUSSION

When considering any island flora it is interesting to speculate on the biogeographical relationships with the neighbouring island groups and continents. In the case of myxomycete floras it would be incautious to assume too much from field observations made over a short period of time. Even when long-term data are available it must be remembered that with efficient and effective spore dispersal and transport myxomycetes are not restricted by ocean barriers. Where they occur suggests more about the microecology and local climatic conditions than the geographical limitations of species.

In the present study the 55 species recorded include 40 which are more or less cosmopolitan, occurring equally commonly in tropical and temperate regions; eight species are scattered throughout the world and are not common in any region; five species are scattered in and restricted to the tropics. Two species were previously known from single regions, *Didymium floccosum* from the Mussoorie Hills, India, and *Physarum dictyosporum* from North America. In all, ten species are newly recorded for Africa *sensu lato*.

Of the total, 50 species are known from India and Sri Lanka, while 43 are recorded from Africa and the same number from the Malesian region. There is a slight suggestion in the flora that the species have a closer similarity with India rather than with Africa, a bias which may be shared by the lichen flora (P.W. James, personal communication.)

The other island groups in the Indian Ocean have not been intensively searched for myxomycetes. Patouillard (1928) listed ten species from Madagascar and a few have been added since. Eight of these are known from Aldabra. Twelve myxomycetes are recorded from Mauritius (Wiehe, 1948) of which five have been found on Aldabra. There is one record, of *Didymium difforme*, from the Seychelles (specimen in K.) The only other coral islands which have been investigated are the Marshall group in the Central Pacific (Rogers, 1947) where sixteen species are listed, twelve of these being found on Aldabra. Finally, the atolls forming the Caroline Islands have yielded *Physarum nicaraguense*, also known from Aldabra.

The richness of the myxomycete flora of Aldabra appears to result from an adequate rainfall, the presence of a varied, and often deep, litter layer under woody plants (26 species of foliicolous myxomycetes), the piles of rotting coconut husks and related litter (20 species) and reasonable quantities of rotting wood (15 species). These microhabitats in turn reflect the relatively small amount of human disturbance of the island's ecosystem (Beamish, 1970).

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ENTOMOFAUNA OF COCOS ISLAND, COSTA RICA

by Charles L. Hogue and Scott E. Miller

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ENTOMOFAUNA OF COCOS ISLAND, COSTA RICA

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INTRODUCTION

Cocos Island, famed as a treasure island where a fabulous cache of Spanish gold allegedly still lies hidden, is far more significant as a repository of scientific wealth. Located in the tropical eastern Pacific, approximately midway between the country of Costa Rica and the Galápagos Archipelago, its natural heritage has considerable bearing on many biological and geological questions. It is our opinion that the island is of special importance in the interpretation of Cenozoic Middle American zoogeography because it alone, of all the far eastern, tropical Pacific oceanic islands, is situated in a wet climatic zone and retains a forest vegetation probably more like that of the original mainland source areas than the mainly xeric or barren Galápagos, Revillagigedo, Clipperton and Malpelo islands. The high rainfall is also responsible for numerous streams whose aquatic invertebrate organisms are of very great analytic value in zoogeography because of their low vagility.

An extensive, but practically unknown, insect fauna is found on Cocos Island. A cursory census made from the literature by Hertlein (1963) revealed only 41 species of insects, myriopods and arachnids, a number far short of the 362 we can now list (see below) and the estimated 800 which we think actually may occupy the island. This lack of knowledge has prevented the inclusion of the island in a recent comparison of the faunas of South American Pacific islands (Kuschel 1963). But believing, as do many zoogeographers, that insects constitute especially useful subjects for studying the principles and historical patterns of animal geography, we have undertaken the task of making a complete assessment of the entomofauna of Cocos Island. In order to inform our colleagues of our progress and perhaps generate interest among uninitiated researchers, we are issuing this progress report on our studies to date. We invite comment, criticism and suggestions and, particularly from those who may wish to collaborate in specific aspects of the projects (we hope by making determinations), we solicit assistance.

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COCOS ISLAND

The following background outline on Cocos Island has been extracted from various sources, mainly Hertlein (1963), Fournier (1966) and Hancock and Weston (1960). Other important references are cited in context.

Location.-- $5^{\circ} 32' 57''$ North Latitude- $86^{\circ} 59' 17''$ West Longitude.

Approximately midway between mainland Costa Rica (500 km, 300 mi) and the Galápagos Islands (630 km, 350 mi).

Size.-- Circumference about 23.3 km^2 (13 naut mi, 14.6 stat mi). Area about 46.6 km^2 (18 mi^2 , 11,500 acres). Dimensions 5.6 km (3.5 mi) by 5.4 km (3.38 mi).

Topography.-- (No detailed topographic map ever made). Abrupt coast with towering, high (180 m, 600 ft) precipitous cliffs rising from a narrow shore shelf. Irregular, hilly terrain inland. Highest peak (Cerro Yglesias) 849 m (2,788 ft) in elevation. Underwater profile of stepwise shelves, virtually no intertidal zone, shallow submerged fringing coral reef, sand and rubble falling off abruptly to several hundred meters. Coastline irregular, two main bays affording anchorage and small sandy beaches.

Geology.-- Poorly studied. Wholly volcanic (presence of sedimentary rocks unconfirmed). Chiefly conglomerates, tuffs and lava flows of labradorite-andesite and related rock types. Soil mostly heavy yellow clay overlain with thin humic layer. Landslides common.

Climate.-- (No permanent meteorological station until recently). Tropical, wet (Köppen Af). Air temperatures range between 20°C (68°F) - 33.3°C (92°F). Heavy rainfall throughout year, probably over 60 cm total; short, relatively dry season January-March. Island situated in eastward-flowing equatorial counter-current (occasional current shifts to westward). Heavy orographic mists and rains often veil island.

Hydrology.-- Numerous streams, many of which plunge over peripheral cliffs as picturesque waterfalls. Reports of inland, large pond or lake unconfirmed.

Flora.-- (See also Fosberg and Klaw, 1966 and Gómez, 1975, 1976). Vegetation luxuriant, dense. Tropical wet forest (Holdridge). Disharmonious species composition; palms, ferns and cecropia trees most prominent. Over 200 plant species presently recorded (155 vascular, 48 non-vascular).

Fauna.-- Few indigenous truly terrestrial vertebrates: two lizard species (Anolis and Sphaerodactylus) and four birds (Cocos Island Finch, Yellow Warbler, Cocos Island Cuckoo, Ridgeway's Flycatcher). Also, numerous sea birds (see Slud, 1967), and several introduced birds and mammals (deer, pigs, cats and rats). Terrestrial invertebrates include several species of land snails (Hanna & Hertlein, 1938), hermit crabs, land crabs (Cardisoma crassum), earthworms, etc. Stream and marine fish fauna associated with the island extensive and diverse (under review by Lavenberg and Bussing). Goats,

monkeys, parrots and other birds intentionally introduced to the island at various times have not become established.

History.-- "Cocos Island is best known from traditional accounts of treasure reputed to be buried there about 1819-1820, the value variously estimated at 60 to 100 million dollars. A large portion of this is supposed to have been placed there by a pirate, Benito Bonito (alias Bennett Graham) of the Relampago, who looted cities and ships along the coast of South America. Tradition has it that additional treasure was buried on the island by Captain William Thompson.

According to this latter story, a revolution in Peru, in 1820, led authorities in Lima to entrust for safe-keeping to Captain Thompson of the Mary Dear the "treasure of Lima," gold and jewels said to be valued at many millions of dollars. The vessel made its way to Cocos Island where the treasure was reputedly buried at Wafer Bay. The subsequent search with expenditure of much time, energy and money has led to over 400 expeditions..." (Hertlein, 1963:225).

Discovery.-- First shown on map by Desliens in 1541, probably known generally to seafarers from at least that date.

Sovereignty.-- Unclaimed officially until early 1800's, documented 1851 by Costa Rica. Presently claimed and administered by that country.

Settlement.-- No permanent human settlement has survived on the island. Numerous temporary habitations have been established, mostly by treasure hunters and adventurers. August Gissler was a resident for 18 years (1894-) and acted as ex officio governor. Cocos Island was designated a national park by the Costa Rican government in 1979 and a garrison of national guard placed in residence.

PAST EXPEDITIONS AND INSECT COLLECTIONS

There have been very few scientific expeditions to Cocos Island, a sad commentary on human values since there have been scores of "treasure hunting expeditions". Below is a list of those, some mere brief passing excursions, on which significant entomological collections or observations were made.

1.	DATE:	28 February 1891
	NAME:	Albatross Expedition
	COLLECTOR:	Unknown
	LOCALITY:	Unknown
	SPONSOR:	United States Fish Commission
	VESSEL:	steamer <u>Albatross</u>
	COLLECTIONS:	Four specimens (<u>Cocconotus bellicosus</u> - holotype; 2 cicadas, 1 scorpion). In Smithsonian Institution, Washington, D. C.
	REFERENCE:	Smithsonian Institution Registrar, accession file 25157

-
2. DATE: June, 1898
 NAME: None
 COLLECTORS: Anastasio Alfaro, Enrique Pittier
 LOCALITIES: Chatham and Wafer Bays
 SPONSOR: Costa Rican Government
 VESSEL: Poás
 COLLECTIONS: Various, not known for certain if significant insects were taken.
 REFERENCE: Instituto Geográfico Costa Rica, 1963:123.
-
3. DATE: 29 June - 3 July 1899 (5 days on island)
 NAME: Hopkins Stanford Galápagos Expedition
 COLLECTOR: Robert E. Snodgrass
 LOCALITY: Unknown
 SPONSOR: Stanford University
 VESSEL: Schooner Julia E. Whalen
 COLLECTIONS: Natural History Museum of Los Angeles County (part, via Stanford University) and perhaps National Museum of Natural History, mostly in very poor condition.
 NOTES: Heidemann 1901:370 cites a cicada taken by the expedition on Cocos Island 2 February 1899, date wrong?
 REFERENCE: Anon., 1901.
-
4. DATES: 11-16 January 1902 (entire trip; probably fewer days spent at the island)
 NAME: None
 COLLECTOR: Pablo Biolley
 LOCALITY: Unknown
 SPONSOR: Government of Costa Rica: Museo Nacional and Instituto Fisicogeográfico
 VESSEL: Turrialba
 COLLECTIONS: Quantity unknown; specimens dispersed among collections of (mostly European) specialists.
 REFERENCES: Biolley, 1907:5; Brölemann, 1903:128; Emery, 1919:37.
-
5. DATES: 3-13 September 1905
 NAME: California Academy of Sciences Galápagos Expedition
 COLLECTOR: Francis X. Williams
 LOCALITY: Chatham and Wafer Bays
 SPONSOR: California Academy of Sciences
 VESSEL: Schooner Academy
 COLLECTIONS: Apparently a small but undetermined number of specimens; deposited in the California Academy of Sciences, San Francisco.
 REFERENCES: Slevin, 1931:27-32; Stewart, 1912:375-377.
-
6. DATE: 1924 (1 day on island)
 NAME: Saint George Expedition
 COLLECTORS: C. L. Collenette, Evelyn Cheesman and Cynthia Longfield
 LOCALITIES: Wafer Bay, Río Genio
 SPONSOR: British Museum (Natural History)
 VESSEL: Steam yacht St. George

COLLECTIONS: Possibly none due to short stay; British Museum (Natural History)?

REFERENCE: Collenette, 1925; Chubb, 1933:1.

7. DATES: 15-24 May 1925
NAME: Arcturus Oceanographic Expedition
COLLECTOR: William Beebe
LOCALITIES: Chatham and Wafer Bays
SPONSOR: New York Zoological Society
VESSEL: Steam yacht Arcturus
COLLECTIONS: Unknown
REFERENCES: Beebe & Rose, 1926. Beebe, 1926:410-412.

8. DATE: 2 Jan. 1928 (one day on island?)
NAME: Cornelius Crane Pacific Expedition
COLLECTORS: Karl P. Schmidt (and Frank C. Wonder?)
LOCALITY: Chatham Bay
SPONSOR: Field Museum of Natural History
VESSEL: yacht Illyria
COLLECTIONS: 1000 miscellaneous insects plus 75 vials of termites collected on total expedition; number from Cocos Island unknown. Repository of latter either Field Museum of Natural History, Chicago or American Museum of Natural History.
REFERENCES: Wenzel, 1978; Shurcliff, 1930:60-70, 293-4.

9. DATES: 17-19 April 1930
NAME: Vincent Astor Expedition to the Galápagos Islands
COLLECTOR: No entomologist on expedition
LOCALITIES: Chatham & Wafer Bays
SPONSOR: New York Zoological Society?
VESSEL: yacht Nourmahal
COLLECTIONS: Only the allotype of the cicada, Proarna cocosensis Davis known. In American Museum of Natural History, New York.
REFERENCES: Svenson, 1935; Townsend, 1930:152-153.

10. DATES: 2-4 February 1932; 28 Feb.-3 Mar. 1933
NAME: Allan Hancock Pacific Expeditions (entomological results only on these two expeditions)
COLLECTOR: John S. Garth
LOCALITIES: Wafer and Chatham Bays
SPONSOR: Allan Hancock Foundation, University of Southern California, Los Angeles
VESSEL: motor cruiser Velero III
COLLECTIONS: Small number of specimens; deposited at the Allan Hancock Foundation, University of Southern California, Los Angeles.
REFERENCES: Garth, 1932; 1933. Clark, 1938

11. DATE: 28 June 1932
NAME: Templeton Crocker Expedition
COLLECTOR: Maurice Willows, Jr.

- LOCALITIES: Wafer and Chatham Bays
 SPONSOR: California Academy of Sciences
 VESSEL: Schooner Zaca
 COLLECTIONS: Unknown quantity; deposited in the California Academy of Sciences, San Francisco. Hogue unable to find, Dec. 1979.
 REFERENCE: Crocker, 1933
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12. DATES: 10 April 1939; 10 February 1936 (two separate expeditions)
 NAME: None
 COLLECTOR: Reinhold L. Fricke
 LOCALITY: Unknown
 SPONSOR: Carnegie Museum of Natural History
 VESSEL: yacht Vagabondia
 COLLECTIONS: Only 4 specimens of Historis odius, 10 Feb. 1936 (see Miller notes) known. Deposited in the Carnegie Museum of Natural History, Pittsburgh.
 REFERENCE: Trimble, 1943
-
13. DATES: 21 February-28 April 1963
 NAME: None
 COLLECTOR: Paul Slud
 LOCALITIES: Wafer Bay and vicinity
 SPONSOR: American Museum of Natural History
 VESSEL: chartered fishing boat, the Elinor
 COLLECTIONS: 223 specimens deposited in the American Museum of Natural History, New York.
 REFERENCE: Slud, 1967:263-4; 1978
-
14. DATES: 8-9 March 1964 (ashore overnight)
 NAME: Galápagos International Scientific Project
 COLLECTORS: Robert O. Schuster, Guillermo Kuschel, David Cavagnaro, Peter D. Ashlock
 LOCALITY: Chatham Bay
 SPONSORS: University of California, Charles Darwin Foundation and California Academy of Sciences
 VESSEL: Golden Bear
 COLLECTIONS: Approximately 1000 specimens; deposited in the California Academy of Sciences, San Francisco.
 REFERENCE: Schuster & Grigarick, 1966:315.
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15. DATES: 22-23 January 1967
 NAME: None
 COLLECTOR: Ira L. Wiggins
 LOCALITY: Chatham Bay
 SPONSOR: University of California at Los Angeles
 VESSEL: Chartered fishing boat Five Bells
 COLLECTIONS: Approximately 1800 specimens; deposited in the California Academy of Sciences, San Francisco. Malaise trap only.
 REFERENCE: Wiggins, 1979
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16. DATES: January-April 1970 (14 weeks on island)
NAME: None
COLLECTOR: Luis Diego Gómez
LOCALITY: General
SPONSORS: Gómez, Field Museum of Natural History, Society of Sigma Xi
VESSEL: Dona Dina (chartered shrimp trawler from Puntarenas)
COLLECTIONS: Approximately 400 specimens; deposited with the National Museum of Natural History, Washington, D. C.
REFERENCE: Gómez, 1975:33.
-
17. DATES: March 1972 (12 days)
NAME: Tropical Science Center Expedition
COLLECTORS: L. D. Gómez, J. Tosi, L. Poveda, R. Swain, M. Hudson
LOCALITIES: Wafer Bay and nearby forests, Cerro Yglesias
SPONSORS: Participants
VESSEL: MV Fort Ross
COLLECTIONS: Moths, plants. Museo Nacional de Costa Rica, destroyed by fire (except ants?).
REFERENCE: Gómez, pers. comm.
-
18. DATES: 17-22 April 1975 (5 days on island)
NAME: Doheny Expedition
COLLECTOR: Charles L. Hogue
LOCALITY: Wafer Bay
SPONSOR: Natural History Museum of Los Angeles County
VESSEL: Qualifier 105
COLLECTIONS: 4700 specimens of insects and other terrestrial arthropods: deposited in the Natural History Museum of Los Angeles County.
REFERENCE: Hogue, 1975
-
19. DATES: February 1976 (20 days)
NAME: Cousteau Society Expedition
COLLECTOR: Luis Diego Gómez
LOCALITY: General, especially Yglesias Bay
SPONSORS: Cousteau Society and Nacional Museum of Costa Rica?
VESSEL: R/V Calypso
COLLECTIONS: National Museum of Natural History, Washington, D. C., Nacional Museum of Costa Rica?
REFERENCES: Gómez, 1976:97; 1977
-
20. DATES: 20-30 March 1978 (7 days on the island)
NAME: Steele Expedition
COLLECTORS: Charles L. Hogue and Scott E. Miller
LOCALITIES: Wafer Bay and Río Genio to waterfall
SPONSOR: Natural History Museum of Los Angeles County
VESSEL: Yacht Jubilee
COLLECTIONS: 9650 specimens of insects and other terrestrial arthropods; deposited in the Natural History Museum of Los Angeles County.
REFERENCE: Hogue, 1978
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| 21. | DATES: 8-11 April 1979
NAME: None
COLLECTORS: Robert E. Silberglied, N. Smyth and R. Foster
LOCALITIES: Chatham, Wafer and Yglesias Bays
SPONSOR: Smithsonian Tropical Research Institute, Panamá (for National Park Service of Costa Rica)
VESSEL: R/V <u>Benjamin</u>
COLLECTIONS: Approximately 1300 specimens deposited in the Museum of Comparative Zoology, Harvard University.
REFERENCES: Silberglied, 1979a; 1979b |
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| 22. | DATES: 24 February 1980-24 March 1980
NAME:
COLLECTORS: Thomas W. Sherry & Tracey K. Werner
LOCALITIES: Chatham & Wafer Bays, Río Genio, Interior, Cerro Yglesias
SPONSORS: American Museum of Natural History (Chapman fund), Western Foundation of Vertebrate Zoology, Natural History Museum of Los Angeles County, University of California at Los Angeles, participants
VESSEL: " <u>Fuerza Publica #405</u> " of Costa Rica
COLLECTIONS: Approximately 4200 arthropod specimens. Deposited in the Natural History Museum of Los Angeles County and Museo Nacional de Costa Rica.
REFERENCE: Sherry & Werner, pers. comm. |
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RESEARCH ACTIVITIES

Our research work on the Cocos Island entomofauna to date has been organized around five objectives: (1) collection of and accumulation of material, (2) curation of material, (3) identification of specimens, (4) literature survey and (5) solicitation of the help of contributors.

1. Original material has been collected on two field trips to Cocos Island, the first by Hogue only, the second by both Hogue and Miller. Summary reports of these expeditions are available (Hogue, 1975; Hogue, 1978).

We have been successful also in locating a number of other collections. These are varied in size and taxonomic coverage and they add substantially to the resources for the total study. They are identified above in our listing of past entomological expeditions to the island (PAST EXPEDITIONS & INSECT COLLECTIONS).

Most of this material has been scattered among numerous specialists and institutions. For purposes of our study we are attempting to bring it together in Los Angeles temporarily for assessment and identification and would appreciate the loan of any specimens from individual or other expeditionary efforts not known to us. As soon as possible after material is worked up it will be returned to its original repository.

From our own holdings and wherever cooperation can be obtained from others we are building a representative collection of all taxa to be deposited in the National Museum of Costa Rica for the benefit of local workers; that institution should be considered a general repository for Cocos Island taxonomic studies.

2. Most of our material and that borrowed from the other repositories has been mounted and labelled and is organized systematically in the Natural History Museum of Los Angeles County. Large numbers of duplicates are being kept in mass lots with the pinned samples and can be mounted as desired by contributors. A large number of microlepidoptera remains unmounted and unpinned because of the lack of trained preparators. This deficiency will require many months to remedy because of the little time available for us to prepare the specimens.

3. Identifications, to date, are far from complete. Refer to the list of taxa which have been determined (TAXA IDENTIFIED) to determine the degree to which this phase of research has been accomplished.

4. During all phases of research we are recording literature pertinent to entomological aspects of Cocos Island. Originals and copies of these references are being assembled into a library for our use and reference by others. Complete citations to most items so far discovered are given at the terminus of this report (LITERATURE). In addition to a manual search of published sources and consultations with specialists, our literature survey has included online searches of the following computerized data bases: BIOSYS PREVIEWS (Biosciences Information Service, 1979-1979), CAB ABSTRACTS (Commonwealth Agricultural Bureaux, 1973-1979), COMPREHENSIVE DISSERTATION ABSTRACTS (1861-1979), CURRENT RESEARCH INFORMATION SYSTEM (USDA Cooperative State Research Service, 1974-1979), NATIONAL TECHNICAL INFORMATION SERVICE (1964-1979), SSIE CURRENT RESEARCH (Smithsonian Science Information Exchange, 1977-1979) and AGRICOLA (National Agricultural Library, USDA, 1970-1979).

One must use care in searching the literature to be aware of the frequent confusion of the Indomalayan Cocos (Keeling) Islands group with Cocos Island, Costa Rica.

5. Over sixty contributors, listed below (LIST OF CONTRIBUTORS), have thus far been enlisted to aid in various aspects of the project, mostly to identify specimens within their fields of taxonomic expertise. Some taxa remain completely unpatronized for which we are still soliciting help (see TAXA IDENTIFIED).

One of us (Miller) spent 3 months (June to September 1979) working on this research on site in the entomological departments of the National Museum of Natural History, Smithsonian Institution (Washington, D. C.), American Museum of Natural History (New York), Museum of Comparative Zoology (Harvard University, Cambridge) and Canadian National Collection (Ottawa). The visits were made possible by a Smithsonian Short Term Visitor Appointment and an American Philosophical Society grant. Considerable progress was made, with the help of resident specialists, on all phases of the study but most significantly with determinations of beetles and microlepidoptera. Miller also spent several weeks at the National Museum of Natural History and other eastern institutions in 1978 & 1980, the time partly spent on these studies.

TAXA IDENTIFIED

We will not take space in this report to fully annotate and document all records of the species presently known to occur on Cocos Island. The following list is intended to provide an idea of the degree to which we have progressed in the determinative phase of the project and present a very general idea of the character of the island's insect and terrestrial arthropod fauna. Some comments are included, however, to indicate special problems or needs for determinative assistance. A full accounting of collection and literature records is being maintained on forms in a duplicate master file, a copy kept with each of us.

INSECTA

Note: 1. Tentative status of occurrence:

- (En) = Endemic
- (Au) = Autochthonous
- (Ad) = Adventive
- () = Unknown
- (Mi) = Migrant

2. Taxa within major groups are listed in alphabetical order.

PROTURA, DIPLURA

Not yet recorded.

COLLEMBOLA

A few dried, shrivelled specimens have turned up in Malaise trap collections.

No material properly collected yet.

THYSANURA

Not yet recorded.

MICROCORYPHIA

Machilidae

1. Probably Neomachilellus sp.

EPHEMEROPTERA, PLECOPTERA

Not yet recorded.

ODONATA

Aeshnidae

2. Au Genus species

Libellulidae

3. Au Pantala flavescens (Fabricius)

Zygoptera

4. Genus species

DERMAPTERA

Forficulidae

5. Ad Ancistrogaster mixta Borelli

Carcinophoridae

6. Ad Anisolabis maritima (Gene)

30. Au Amphiareus constrictus Stål⁰
 31. En Asthenidea nebulosa (Uhler)
 32. En Lasiochilus ashlocki Herring
 33. Au Lasiochilus pallidulus Reuter
 Lygaeidae
 34. En Ozophora new species. Under study by Slater.
 Mesoveliidae
 35. En Mesovelia new species. Under study by Polhemus.
 Miridae
 36-38. 3 genera, 1 species each. Under study by Schuh.
 Nabidae
 39. Nabis sp.
 Pentatomidae
 40. Ad Acrosternum marginatum (P.B.)
 41. En Banasa new species. Under study by Thomas.
 Reduviidae
 42. Probably Gardena sp.

HOMOPTERA

- Aphididae
 43. Genus species. Sherry
 Cicadellidae
 44-47. At least 4 genera with one species each.
 Cicadidae
 48. En Proarna cocosensis Davis
 Fulgoroidea
 49-68. Numerous families and genera, with at least
 20 species.
 Coccoidea
 69. Coccus hesperidum Linnaeus
 (= Lecanium hesperidum pacificum Kuwana)

THYSANOPTERA

Not yet recorded.

NEUROPTERA

- Chrysopidae
 70. Chrysopa sp.
 Hemerobiidae
 71. Genus species

MECOPTERA

Not yet recorded.

TRICHOPTERA

72. Oecetis Punctatus Group

LEPIDOPTERA

"Microlepidoptera"

- Blastobasidae
 73-74. Genus 2 (or more) species.
 Choreutidae. Under study by Heppner.
 75. En Tortyra new species
 76. En Brenthia new species
 Cochylidae
 77. En Cochylis new species

78. En Genus species
Cosmopterygidae
79. Au Cosmopterix attenuatella Walker?
80-81 Genus 2 species
- Gelechiidae
82. Au Semophylax apicepuncta (Busck)
- Glyphipterygidae. Under study by Heppner.
83-84. En 2 Genera 1 species each
- Gracilariidae
85. En "Acrocercops" (sens. lat.) new species
86. En New Genus
87. En Genus new species?
- Heliodinidae
88. Schrechensteinia probably erythriolla Clemens
- Pterophoridae
89. En Ochyrotica new species near fasciata Walsingham
- Pyralidae. Under study by Munroe.
- Crambinae
90. Au Argyria lacteela (Fabricius)
91. En Microcrambus new species. Under study by Miller.
92-93. En 2 Genera 1 species each
- Nymphulinae
94. En Undulambia new species near forecosta (Dyar)
95-98. Genus 4 species?
- Phycitinae
99. Genus species
- Pyraustinae
100. En Mecyna cocosica Munroe
101. Terastia meticulosalis Guenée(?)
102-108. Genera 7 (or more) species?
- Tineidae. Under study by Davis.
109. Decadarchis sp.
110-111. Opogona 2 spp.
112. En New genus
113. En New genus near Delotoma
114-115. 2 Genera 1 species each
- Tortricidae. Under study by Miller.
116. En Cydia new species
117. Polyortha sp.
118. Au Tsinilla lineana (Fernald)
119-121. 3 Genera
- "Macrolepidoptera"
- Geometridae
122. Eupithecia sp.
123. En Oxydia new species. To be described by Donahue.
124. Psaliodes sp.
125. Synchlora sp. near tenuimargo (Warren)
126. Genus near Metasiopsis sp.
127. Genus near Pleuroprucha sp.
- Noctuidae. Under study by Hayes.
128. Ad Callopietria floridensis (Guenée)
129. Ad Gonodonta clotilda (Stoll)
130. Melipotis sp.

131. Spodoptera prob. dolichos (Fabricius).
 132. Paectes sp. near nyctichroma Hampson
 133. Mocis sp. near disseverans Walker
 134. Numerous additional genera and species.

Sphingidae

135. Au Pachylia ficus Linnaeus. Brown and green forms.
 136. Au Herse cingulata Fabricius.
 137. Xylophanes tersa (Linn.)?

Butterflies

Danaidae

138. Mi Danaus plexippus (Linnaeus). Sight record only
 (Hogue & Miller).

Nymphalidae

139. Au Historis odius (Fabricius). Probably the only
 resident butterfly species.
 140. Timetes sp. Sight record only (Garth).

Family unknown

141. Species unknown: "A species of delicate build."
 Williams 1911:296.

DIPTERA

Asilidae

142. Eumecosoma new species in "Hirsutum complex".
 Under study by Fisher.

Bombyliidae (Wiggins)

143. Genus species. Questionable. Specimen not seen.

Calliphoridae

144. En Phaenicia deceptor Curran
 145. Phaenicia purpurescens (Walker)

Canaceidae

146. En Paracanace hoguei Mathis & Wirth

Cecidiomyidae

- 147-151. Several genera and species

Ceratopogonidae

152. Au Atrichopogon gordonii Macfie
 153. Atrichopogon sp. in Websteri complex
 154. Au Forcipomyia stylifera Lutz
 155-159. Several additional genera? species?

Chironomidae

160. En Thalassomyia cocosensis Hashimoto
 161-171. Several additional genera species

Chloropidae

- 172-173. 2 species

Culicidae

174. En Culex dohenyi Hogue
 175. Limatus sp. near durhamii Theobald

Dolichopodidae

- 176-180. Several genera, species?

Drosophilidae

181. Genus species

Empididae. Under study by Wilder.

- 182-184. Syneches 3 species

185. Chersodromia sp.
 186. Roederiodes sp.
 Ephydriidae. Under study by Mathis
 187. En Paralimna meridionalis Cresson
 188-190. 2 - 3 additional genera? species?
 Fungivoridae
 191-193. Several species
 Lauxaniidae
 194. Genus species
 Micropezidae
 195. Genus species
 Muscidae - Anthomyidae
 196. Limnophora pica (Macquart)
 197. Ad Ophyra aenescens (Wiedmann)
 198-202. Several additional genera species?
 Otitidae. Under study by Steyskal.
 203-204. En Euxesta 2(3?) new species
 Phoridae
 205. Genus species
 Psychodidae. Under study by Duckhouse.
 206. En Psychoda new species
 207. Genus probably new species
 Sarcophagidae
 208-210. Several genera? species?
 Sphaeroceridae
 211. Genus species (see Gómez, 1977)
 Stratiomyidae
 212. En Merosargus insularis Curran
 213. Genus species
 214. Cyphomyia sp.
 Tipulidae. Under study by Byers and students.
 215. Gonomyia sp.
 216. En Helius new species
 217. En Limonia (Caenolimonia) new species
 218-221. En Limonia (Geranomyia) 4 new species
 222. En Orimarga (Diotrepha) new species
 223-224 Limonia (Rhipidia) 2 new species

SIPHONAPTERA

Not yet recorded.

COLEOPTERA

- Anobiidae
 225. Protheca probably new species near undulata White
 Anthribidae
 226-227. 2 genera, 1 species each.
 Brentidae
 228. Rhaphirhynchus sp. near panamensis Senna
 Buprestidae
 229. Genus species. Sherry.
 Carabidae. Under study by Erwin.
 230. Perigona sp.
 231. Platynus new species

232. Au Acanthoderes circumflexus Jacquelin duVal
 233. En Acanthoderes cocoensis Linsley & Chemsak
 234. En Adetus nesiotes Linsley & Chemsak
 235. En Anisopodus longipes Linsley & Chemsak
 236. Au Parandra glabra (DeGeer)
 237. Au Taeniotes hayi (Mutchler)
 238. En Urgleptes kuscheli Linsley & Chemsak
- Chrysomelidae
 239. Lema sp.
- Cleridae
 240. Mi Necrobia rufipes (DeGeer)
- Coccinellidae
 241. Au Coleomegilla maculata (DeGeer)
 242. Au Cycloneda sanguinea (Linnaeus)
- Colydiidae
 243. Synchita sp. near dubia Hinton
- Curculionidae
 244. Anchonus sp. (spp.?)
 245. Genus near Copturus. Under study by Hespenheide.
 246-247. Cossonus 2 species
 248. En Dryophthorus cocosensis Champion
 249. Dryophthorus? sp.
 250. Genus near Epicaerus
 251. Eubulus sp.
 252. Graphonotus sp. near leporinus Champion
- Dytiscidae. Under study by Spangler.
 253. Au Copelatus caelatipennis fragilis Sharp
 254-255. Genera? 2 species
- Elateridae
 256. Dromaeolus sp.
 257. Au Ischiodontus anceps Cand.
 258. Au Ischiodontus tuspanus Cand.
 259. Au Lissomus bicolor Cherr.
 260. Au Physorrhinus cruciatus Champion
 261. Plesiofornax near sublucidus Bonv.
- Eucnemidae
 262. Fornax sp.
- Helodidae
 263. Genus new species. Under study by Klausnitzer.
- Histeridae
 264. Paromalus sp. (Silberglied)
- Languriidae
 265. Hapalips sp.
- Mordellidae
 266. Falsomordellistena (Falsomordellistenoda) sp.?
- Nitidulidae
 267. Stelidota sp.
 268. Genus species
- Oedemeridae
 269. Au Hypasclera costata (Champion)

- Passalidae
270. En Popilius lenzi Kuwert
Ptiliidae
271. Actinopteryx sp.
Ptilodactylidae
272. Ptilodactyla spp.
Rhipiceridae
273. Callirhipis new species near affinis vanEmden.
Under study by Miller.
Scolytidae
274. Phleotribus sp.
275. Xyleborus affinis Eichhoff
276. Xyleborus ferrugineus (Fabricius)
277. Xyleborus perforans Wollaston
Staphylinidae
278. Clavilispinus sp.
279. En Holotrochus new species. To be described by Irmeler.
280. Lispinus sp.
281. Nacaeus sp.
282. Scopaeus (sens. str.) sp.
283. Thinodromus sp.
284. Xantholinina Genus species
Aleocharinae
285. Genus species
Tenebrionidae
286. Neomida new species in ms. by Triplehorn.
287. En Prateus new species. Under study by Spilman.
288. Strongylium 3 spp.
STREPSIPTERA
289. Elenchus koebelei Pierce
HYMENOPTERA
Bethyidae
290. possibly Disсомphalus sp.
291. Genus species
Braconidae
292-293. Apanteles 2 spp.
294. Bracon sp.
295-296. Heterospilus 2 spp.
Chalcidoidea
297. Spilochalcis sp.
Dryinidae
298. Genus species
Eucharitidae
299. Oraesema sp.
Eucoilidae
300. possibly Trybliographa sp.
Eulophidae
301. Genus species
302. Tetrastichus sp.
Eumenidae
303. Pachodynerus nasidens (Latreille)

Formicidae (After Hertlein, partly modified and under study by Snelling).

304. Ad Atta cephalotes (Linnaeus)
 305. En Azteca emmae Forel
 306. En Brachymyrmex longicornis Forel
 307. En Camponotus (Myrmothrix) abdominalis (Fabricius)
 308. En Camponotus (Myrmobrachys) biolleyi Forel
 309. Au Camponotus (Myrmaphaenus) blandus F. Smith
 310. En Camponotus (Myrmaphaenus) cocosensis Wheeler
 311. Au Zacryptocerus cristatus (Emery)
 312. Au Cyphomyrmex rimosus (Spinola)
 313. Au Eciton (Labidus) crassicornis F. Smith
 314. Au Euponera (Trachymesopus) stigma Fabricius
 315. Monomorium floricola (Jerdon)
 316. Au Odontomachus bauri Emery?
 317. Au Odontomachus brunneus (Patton)
 318. Au Pheidole biconstricta bicolor Emery
 319. Au Pheidole punctatissima Mayr
 320. Au Pheidole subarmata Mayr
 321. En Paratrechina guatemalensis cocoensis (Forel)
 322. En Pseudomyrmex belti (Emery)
 323. En Solenopsis geminata Forel
 324. En Solenopsis succinea Emery
 325. En Tetramorium guineense Fabricius
 326. En Wasmannia auropunctata Roger
 327. En Wasmannia auropunctata "var. rugosa" Forel
- Ichneumonidae
 328. Allophrys sp.
 329. Mnioes sp.
- Pteromalidae
 330. Lelaps sp.
- Scelionidae
 331. Oethecoctonus sp.
 332. Trimorus sp.
- Sphecidae
 333. Au Sceliphron assimile (Dahlbom)

ARACHNIDA

ARANEIDA

Araneidae

334. Ad Argyropeira nigriventris Keyserling
 335. Au Eriophora edax (Blackwell)
 336. Eustala sp.
 337. Au Gasteracantha cancriformis (Linnaeus)
 (= biolleyi Banks)
 (= hexacantha (Fabricius))

Ctenidae

338. Ctenus sp.

Hersiliidae

339. Tama sp.

340. Lycosidae
 Lycosa sp.
 341. Salticidae
 Genus species
 Tetragnathidae
 342. Au Leucauge argyra Walckenaer
 343. Au Leucauge nigriventris Keyserling
 Theridiidae
 344. Theridium sp.
 Theridiosomatidae
 345. Au Wendilgarda galapagensis Archer

PHALANGIDA. Under study by Goodnights.

346. En Cynorta insularis Banks
 347. En Pellobundus insularis Banks

SCORPIONIDA

- Scorpionidae
 348. Ad Opisthacanthus lepturus (Palisot de Beauvois)

ACARI

349. A few specimens of unidentified soil mites.

DIPLOPODA

POLYDESMIDA

- Chelodesmidae
 350. En Trichomorpha folium (Brölemann)
 351. En Trichomorpha hyla Hoffmann
 Strongylosomatidae
 352. En Orthomorpha coarctata Saussure

SPIROSTREPTIDA

- Epinannolenidae
 353. En Epinannolene pittieri Brölemann

SPIROBOLIDA

- Rhinocricidae
 354. Au Eurhinocricus biolleyi (Brölemann)

CHILIPODA

355. Au Newportia rogersi Pocock
 356. En Otocryptops melanostoma Newport
 357. Otostigmus scabricaudus (Humbert & Saussure)
 358. Genus species

CRUSTACEA

AMPHIPODA (terrestrial)

359. Genus species (Silberglie)

ISOPODA (terrestrial)

360. Genus species

TARDIGRADA

EUTARDIGRADA

Milnesiidae

361. Au Milnesium tardigradum Doyère

Macrobiotidae

362. Au Macrobiotus richtersi Murray

PRELIMINARY ZOOGEOGRAPHIC INTERPRETATIONS

Of course, it is much too early in our analysis of Cocos Island's insects to generate substantial zoogeographic conclusions, but a few apparent tendencies justify comment.

The entomofauna is definitely and decidedly disharmonious as is normally the case with oceanic islands. Many common, major mainland types are represented by only one or a few species and several are totally absent, notably: Acrididae (grasshoppers); Mantidae (mantids); Coreidae (plant bugs); Membracidae (tree hoppers); many families of Coleoptera (beetles) such as Cantharidae (leather-winged beetles), Erotylidae (fungus beetles), Bostrichidae (branch borers), Meloidae (blister beetles) and Scarabaeidae (scarab beetles); most butterfly families; many families of moths, such as Arctiidae (tiger moths), Sesiidae (clear winged moths), Psychidae (bag-worm moths); many families of Diptera (flies), such as Tabanidae (horse flies), Bombyliidae (bee flies), Syrphidae (flower flies) and Tachinidae (parasitic flies); Hymenoptera (ants, bees, wasps) in general, excepting ants (which are numerous), a few Chalcidoid (micro-parasitic wasps) and one species each of Vespidae and Sphecidae.

Aquatic insects are also conspicuously few in the abundant habitats available in the island's numerous streams and small temporary ponds. The only taxa so far discovered have been Odonata (2 Anisoptera, 1 Zygoptera), Chironomidae (midges), one species each of Trichoptera (caddice-flies), Mesoveliidae (ripple bugs), Dytiscidae (diving beetles) and a few species of Pyralidae, Nymphulinae (aquatic moths).

Most of the main groups of terrestrial Arthropoda are represented, but most sparsely. Spiders and millipedes are the most apparent but centipedes, isopods, and myriapods are also present. Mites have so far been totally ignored by collectors but will probably be found in some proportion.

A high percentage of wood boring, leaf mining and epiphyte dwelling species occurs. This too, is most often the case with oceanic island entomofaunas and indicates the importance of rafting as the major means of colonization. The presence of even a few swift water rheophilic forms, such as the trichopteran and nymphuline pyralids is difficult to explain, although the latter are fairly often encountered on oceanic islands and suggest a dispersal ability not now appreciated.

The taxonomy of Neotropical insects in general is far too rudimentary to permit reliable assignment of nearest relatives or probable source areas of Cocos forms. Even where conspecificity exists with mainland types, differences are often present in the island's population. From the known forms, the following numbers are probably endemic-65, autochthonous-47, adventive-12.

Many zoogeographic deductions depend on knowledge of the island's geologic history. Little information is available, however, and the island seems to be in need of work in this area. Present fragmentary evidence indicates that Cocos Island was formed by the same processes that produced the Galápagos Archipelago and which were also involved with structuring large portions of the Caribbean and Central American isthmus. These involved major tectonic movements in the Nazca and Cocos Plates effecting uplift and magmatic ascensions at the edges of the so-called Galápagos Gore triangle area off the northwest corner of the South American continent (Holden & Dietz, 1972). It is not possible to say when the island first appeared, but dated rock samples indicate volcanic activity 2×10^6 yr. BP=Pliocene (Dalrymple & Cox, 1968). Yet this island may have been only one in a series of emergent land masses projected along the Cocos Ridge. Thus the oldest organisms persisting may be relicts providing clues relative to dispersal and geographic events still much older. Some indication of the existence of such species is found in the fact that at least a few Cocos insect species appear to be part of an Eastern Pacific-Caribbean vicariance track (sensu Rosen, 1975:440). Zorotypus barberi, Paracanace hoguei, and possibly others have known closest relatives or are conspecific with Caribbean island populations. However, studies by Erwin (1979) of Antillan carabids suggest that "... there is much to argue the case for dispersal to the islands by air or wood drift and there is very little to argue the case for vicariance in the sense of Rosen's hypothesis."

We are aware that these track indicators may be spurious since an island (or islands) of much greater age (Tertiary) than Cocos would have to have been present in about the same location for the track to have become established. It is significant in this regard that this track is now defined almost entirely by marine organisms.

WORK NEEDED AND PLANNED

Obviously, the initial phases of a project such as this will require considerable continued attention. We will be seeking additional material and associated literature and data, doubtlessly, for a long time to come. Planned are many publications to describe new Cocos Island taxa; these will be both individual and within more general taxonomic reviews. No attempt will be made to restrict publication to a single journal or format; such is the prerogative of the specialist.

It is now apparent that another field trip (or even series of trips) to the island is sorely needed. Because several important groups of insects have been missed entirely or partially by past collectors, an extended field trip by a team of entomological specialists is warranted. Emphasis would be given to (1) micro-Lepidoptera (specimens mounted in the field), (2) micro-Hymenoptera, (3) soil insects, ectoparasites of the birds and other few vertebrates, and other particular problems for which

specialized collecting techniques must be applied, e. g. pan trapping, micro-mesh Malaise trapping, chemical attractants, Berlese funnel, bait trapping, rearing etc. It is our intent to organize such an expedition, hopefully for a three to four week period in the 1980's.

Final organization and integration of all the data into a zoo-geographic analysis is years off. Ideas can be discussed in future progress reports and short papers may be appropriate for limited topics. With help from our collaborators, we plan to dedicate effort to these ends to the fullest extent that time and resources permit.

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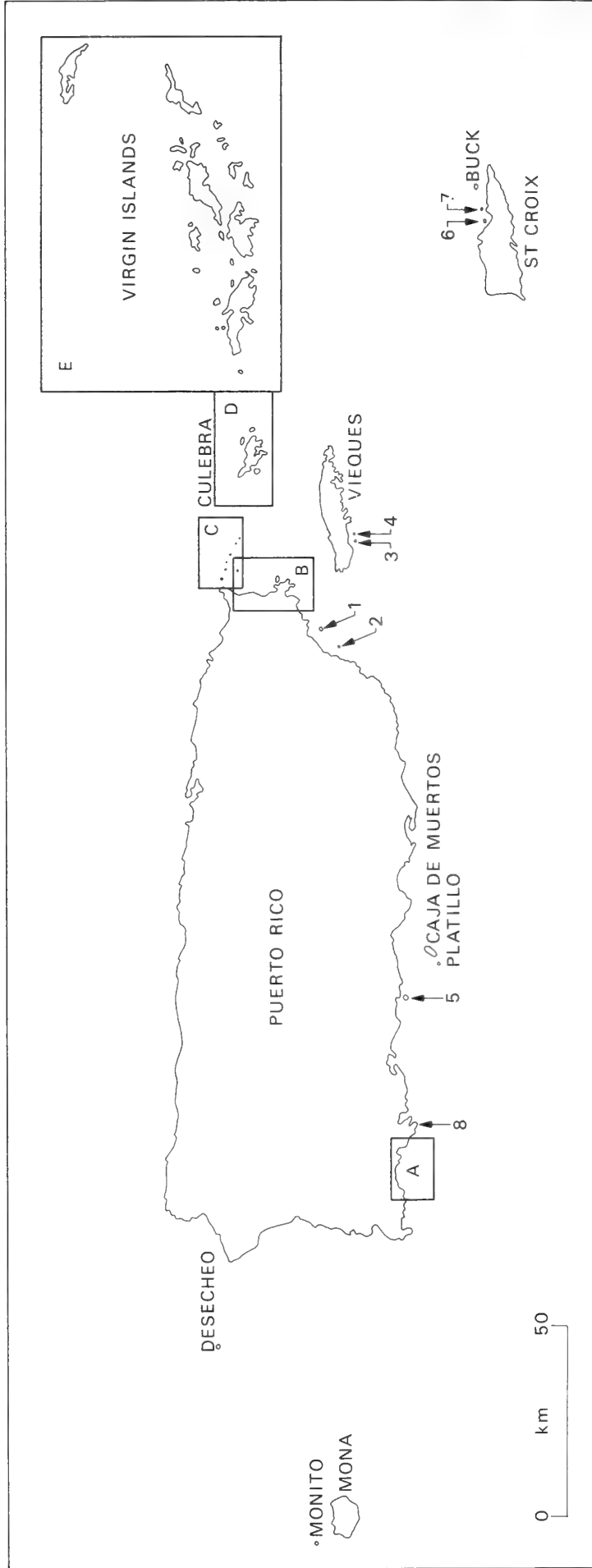


Fig. 1. Map of the Puerto Rican Island Shelf. Rectangles A - E indicate boundaries of maps presented in more detail in Appendix I. 1. Cayo Santiago, 2. Cayo Batata, 3. Cayo de Afuera, 4. Cayo de Tierra, 5. Cardona Key, 6. Protestant Key, 7. Green Key (St. Croix), 8. Caña Azul

BIOGEOGRAPHY OF THE PUERTO RICAN BANK

by Harold Heatwole¹, Richard Levins² and Michael D. Byer³

INTRODUCTION

There has been a recent surge of interest in the biogeography of archipelagoes owing to a reinterpretation of classical concepts of evolution of insular populations, factors controlling numbers of species on islands, and the dynamics of inter-island dispersal. The literature on these subjects is rapidly accumulating; general reviews are presented by Mayr (1963), and Baker and Stebbins (1965). Carlquist (1965, 1974), Preston (1962 a, b), MacArthur and Wilson (1963, 1967), MacArthur et al. (1973), Hamilton and Rubinoff (1963, 1967), Hamilton et al. (1963), Crowell (1964), Johnson (1975), Whitehead and Jones (1969), Simberloff (1969, 1970), Simberloff and Wilson (1969), Wilson and Taylor (1967), Carson (1970), Heatwole and Levins (1973), Abbott (1974), Johnson and Raven (1973) and Lynch and Johnson (1974), have provided major impetuses through theoretical and/or general papers on numbers of species on islands and the dynamics of insular biogeography and evolution. Other work has dealt with specific problems such as dispersal (Gressitt and Yoshimoto 1963, Carlquist 1966 a-c, 1967, Heatwole and Levins 1972b), interspecific competition (Grant 1965, 1966, 1968, Crowell 1962, 1968, Sheppard et al. 1968), effect of disasters (Brattstrom 1963, Sauer 1962), trophic relations (Heatwole 1971, Heatwole and Levins 1972a), colonization (Bassot and Ball 1971, Hunt and Hunt 1974, Becker 1975, Schoener 1975 and Williams 1969), and endemism (Mayr 1965, Heatwole and MacKenzie

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1967, Thornton 1967). In addition there have been a large number of studies treating the distribution and variation of specific groups of organisms on islands and the role of historical factors upon such patterns. With this broadening base of theoretical background and accumulation of information on specific aspects, the first two authors felt it opportune to carry out a comprehensive study of an archipelago containing many islands with a variety of sizes, inter-island distances, topography, vegetation, time of separation, use by humans, and other characteristics, and to study as many aspects of the biogeography of as wide a range of organisms as feasible. Our aim was to look at the subject as a whole and thereby contribute toward a synthetic understanding of the broad aspects of the problem. The original design of the project was presented in an early paper (Levins and Heatwole 1963) and some of the data have been used in general reviews (Levins 1968, 1969, Heatwole 1976a). This paper presents the geography, vegetation, and ecological characteristics of the Puerto Rican Bank and constitutes a background for the rest of the series (some of which have already been published, e.g. Heatwole and Levins 1972b, 1973, Levins and Heatwole 1973, Levins et al. 1973), and for papers by a variety of specialists using the material we collected during our study.

GENERAL DESCRIPTION OF THE REGION AND ITS CLIMATE

The area studied consists of all the islands and cays in the part of the Antillean chain making up the political units of Puerto Rico, the American Virgin Islands, and the British Virgin Islands, sometimes referred to as "Greater Puerto Rico" (Thomas and Schwartz 1966). This includes all land masses between latitudes $17^{\circ} 40' N$ and $18^{\circ} 45' N$ and stretching from the island of Monito (longitude $67^{\circ} 57' W$) to Anegada (longitude $64^{\circ} 16' W$). There are 243 islands and cays in this area (not including those emergent ones periodically washed over by tides and lacking terrestrial vegetation). Of these we surveyed 141, including all of the larger ones. Figure 1 shows a map of the general region and appendix I provides detailed ones of selected areas containing the small cays which were studied. Where possible we followed the official names for islands as listed by the U.S. Department of Commerce, Coast and Geodetic Survey (1962). When no official name could be found, we used names supplied by local fishermen. In cases of nomenclatural disputes among local authorities, we simply chose one of the alternatives. Sometimes we were unable to obtain any name at all and have named islands ourselves.

The climate of the area is tropical and slightly modified by altitude on the larger islands. Rainfall on Puerto Rico is geographically variable, greater in the central mountains than on the coastal plain. In addition, there is a general east-west difference. On the Luquillo Mountains at the northeastern tip of the island, rainfall may exceed 5,080 mm (200 inches) annually; the southwestern lowlands receive less than 750 mm (30 inches) annually (Picó 1954 and see Fig. 2).

The principal Virgin Islands are similar in rainfall to the coastal areas of Puerto Rico; smaller, or more isolated islands represented by Culebra, Vieques, and Mona in figure 2, are more xeric. Mona is drier than its rainfall would suggest, as it is honeycombed with limestone caverns which rapidly drain off surface water.

Temperatures are remarkably uniform seasonally and from year to year in a given locality (Figs. 3, 4). However, on Puerto Rico, temperature follows east-west and altitudinal trends. Guineo Reservoir (elevation 1,000 m) has lower temperatures than Rio Piedras (elevation 15 m) on the northeastern coast. Rio Piedras is in turn cooler than Magueyes Island (10 m) which is representative of the southwestern coast (Fig. 4). The isotherm for mean annual temperatures of 24°C separates the coastal plain and some valleys (below 150 m elevation and where mean annual values exceeding 26°C may occur) from the mountains where mean annual values below 20°C are encountered in the highest parts; the highest temperature ever recorded for the island was 39.5°C , the lowest 5°C (Picó 1954). The hotter coastal areas of southwest Puerto Rico have temperatures similar to those of the principal Virgin Islands (Fig. 4).

Very few meteorological data are available for small cays, though it can be said that most are warm and dry. Figure 3 presents data for Magueyes Island. However, this island is so close to Puerto Rico that it is representative of conditions of coastal southwest Puerto Rico rather than that of more isolated islands. Table 1 gives the average conditions on Cayo Ahogado, a small, nearly barren sandy cay about 1 km east of Puerto Rico, during several days in March, 1966. Figures 5-7 show the details of the daily regimen for the two most extreme days, March 10 which was bright and sunny, and March 19 which was heavily overcast with occasional fine rain. The hottest environment on the cay was the soil surface where midday temperatures exceeded 38°C . At 1 cm and 5 cm below the soil surface, temperatures decreased somewhat but even there reached 30°C or above on hot days. Air temperatures near the ground reached 32°C on warm days, temperature decreased with height above ground. However, except for a few flying forms which experience above-ground temperatures, most inhabitants of small cays are exposed to the thermal conditions near the ground. The low vegetation on Cayo Ahogado ameliorates temperatures somewhat (Fig. 7), although on hot days air temperatures near the surface of small clumps of plants reach $32 - 33^{\circ}\text{C}$. Surface temperatures of leaves were several degrees lower, presumably because of transpiration. Temperature 1 cm down in the soil was as much as 2°C cooler under vegetation than in the open. At 5 cm depth the difference was as much as 4°C . Although the plants were small and sparsely distributed, and hence did not greatly affect environmental temperatures, the few degrees of difference they caused were in a range that may reduce the insolation directly reaching small animals. The effect of unobstructed radiant energy can be seen from the high black bulb (T_{BB}) temperatures (Fig. 5).

The nearly bare, rocky cays probably have even more extreme conditions than Cayo Ahogado, more heavily vegetated ones are probably

more moderate.

The prevailing winds are from the northeast and apparently have been so at least back into the Pleistocene (Kaye 1959). Marine currents are east to west, although a northward current exists between Mona and Puerto Rico, and there is a northward deflection between Vieques and Puerto Rico (Kaye 1959).

Hurricanes usually travel in a general east to west direction.

VEGETATION

The Puerto Rican and Virgin Island flora has been most recently summarized by Britton and Wilson (1923-30) and by Little and Wadsworth (1964). Ecological treatments of a broad nature have been presented by Gleason and Cook (1927), Cook and Gleason (1928) and Dansereau (1966). Only a few articles have dealt with the plants on the small islands (e.g. Britton 1924, 1933 on Hicacos and Culebra, Heatwole *et al.* 1963 on Cayo Santiago and Cayo Batata, and D'Arcy 1971, 1975 on Anegada). Our records are presented in Appendix II.

Analysis of the vegetation of the islands treated here would be a major project in itself and was not possible within the scope of the present investigation. However, broad vegetation types could be recognized and were grouped on a physiognomic basis into 12 categories, most of which include more than one association, or at least varied somewhat in floristic composition from place to place. The classification is not intended to be phytosociological, but rather a useful description of the type and diversity of available structural habitats for animals. The spatial relationships of the categories to one another and to several major environmental parameters are clarified in Figs. 8 and 9. The categories are as follows:

1. Lack of Vegetation. Extensive areas of bare rock or sand, usually coastal, though occurring locally further inland.

2. Succulent Beach Vegetation. Often nearly pure stands of low, succulent, halophytic herbs. *Sesuvium portulacastrum* and *Philoxeris vermicularis*, usually under 30 cm in height, occur alone or in combination on relatively undisturbed gravelly or sandy beaches¹. These two species plus *Batis maritima* and *Salicornia perennis* form various combinations after the elimination of mangrove (8), or in otherwise intermittently-flooded, shallow, saline coastal depressions. *Batis* may reach 70 cm in height.

3. Mixed Beach Vegetation. A variable mixture of herbs (*Cakile lanceolata*), small suffrutescents (*Euphorbia buxifolia*), rhizomaceous

¹ Nomenclature follows Britton and Wilson (1923-30).

grasses (*Sporobolus virginicus*, *Spartina patens*) and creeping vines (*Ipomoea pes-caprae*, *Canavalia maritima*, *Vigna marina*), sometimes with *Sesuvium portulacastrum*. Vegetation usually less than 1 m tall, with low cover. On sand, gravel, or crevices in coastal shelf limestone, fairly resistant to disturbance, and recovers rapidly.

4. Beach Shrubs. Small, scattered shrubs intermixed with herbs and grasses, occasionally containing a high proportion of vines which form a nearly continuous mat. Height usually 1-2 m, found inland from the previous type. Common species are *Suriana maritima*, *Tournefortia gnaphalodes*, and *Thespesia populnea*, with the species characteristic of the previous type (3) as ground cover. Fairly resistant to disturbance.

5. Graminoid. Stands having the graminoid life form dominant, whether composed of true grasses or of sedges. Usually also contains a number of forbs. Usually 1 m or less high, though taller stands are sometimes found. Found in the interior of intermediate-sized and larger islands. Always a disclimax or successional stage in the climatic zone studied (Richards 1957), maintained by grazing, fire, or periodic cutting or mowing. Various graminoid species cover the full range of moisture and edaphic conditions found in the study region.

6. Scrub. Shrubs of various types, cactus, and vines, frequently intermixed with herbs and grasses. Varies from less than 50% to 100% cover, easily penetrable to impenetrable; and less than 1 m to over 2 m, occasionally higher. Frequent dominants are *Croton astroites*, *C. rigidus* (both replaced by *C. discolor* in Anegada), *Lantana involucreta*, *Anthacanthus spinosus*, and *Pithecellobium unguiscati*. A disclimax maintained by overgrazing and overbrowsing, primarily by feral goats, in the interior of intermediate-sized, drier islands and on the leeward (rain-shadow) sides of the largest islands. Shrub stages in the zone where moist forest (10) is climax are successional and consist of more mesomorphic species, often seedlings and saplings of larger, secondary forest trees.

7. Coastal Groves. Stands of small trees or shrubs, inland from (4), ranging from nearly prostrate and less than 1 m in height on windswept coasts and dunes, to 4 m or more in protected sites. Usually provide dense shade with a heavy accumulation of leaf litter. Frequently pure stands of *Coccoloba uvifera* or *Hippomane mancinella*, or mixtures of several to many species; *Elaeodendron xylocarpum*, *Erithalis fruticosa*, *Conocarpus erecta*, and the tree-cactus *Opuntia rubescens* are prominent.

8. Mangroves. Stands of mangrove ranging from scattered saplings about 1 m in height to forests over 10 m, providing rather deep shade, in permanently- or intermittently-flooded depressions behind coasts, and along coasts and on old reefs etc. which are sheltered from wave action. *Rhizophora mangle*, *Avicennia nitida*, *Laguncularia racemosa* and *Conocarpus erecta*, either as single-species stands or in various combinations.

9. Xeric Forest. Deciduous, open forest, frequently with sparse understory of cactus, thorny shrubs, vines, and annual grasses. Height usually over 8 m. Interior of intermediate-sized islands and leeward (rain-shadow) sides of largest islands. May be absent on the windward (humid) sides of the latter, where mesic forest (10) lies adjacent to coastal formations, except where local edaphic-topographic conditions permit xeric forest. Probably includes Dansereau's (1966) category of Semi-deciduous Forest and Little and Wadsworth's (1964) Dry Coastal and Dry Limestone forests. Dominant trees variable from place to place; *Pisonia subcordata*, *Torrubia fragrans*, *Bursera simarouba*, *Citharexylum fruticosum*, *Tabebuia heterophylla*, and the giant cactus *Cephalocereus royeri* are representative.

10. Mesic Forest. Includes a variety of moister, altitudinally-zoned types including those called Moist-coastal, Moist Limestone, Lower and Upper Cordillera, and Lower and Upper Luquillo Forest by Little and Wadsworth (1964), and Lowland Rain Forest, Lower Montane Rain Forest, Montane Forest and Montane Scrub by Dansereau (1966). Physiognomy and floristics are variable (see Beard 1944, Richards 1957). Such a variety is included under one heading since in the region studied, these forests occur only on the largest islands, some types only on Puerto Rico. Finer distinctions would be unnecessary for our purposes.

11. Coconut Groves. Usually planted by man in flat, sandy coastal areas. Light shade, understory usually composed of species of the mixed beach vegetation (3) and variable.

12. Other. Any vegetation not fitting any of the above categories, e.g. crops, ruderals, dooryards, or vegetation of other highly modified areas.

During the survey of a particular island, the vegetation types were recorded, and where feasible, the percentage of the island covered by each one estimated and a rough sketch-map drawn. When only a few individual plants were present on an island, complete censuses were made. In some instances, vegetational reconnaissances were made.

The results are presented in Table 2. By way of summary it can be stated that Puerto Rico contains all the vegetation types outlined (1 - 12). Culebra and Vieques have xeric to mesic forests (9, 10); Mona, Caja de Muertos and Desecheo support xeric forest, all five have a variety of the simplest types (1 - 8). Monito has predominantly scrub (6). The small cays near the southern and southwestern coast of Puerto Rico are mostly mangrove islands (8); those further offshore tend to be sandy and nearly bare (1) or with succulents (2) mixed beach vegetation (3), or beach shrubs (4).

The group of cays extending toward Culebra from northeastern Puerto Rico are mostly steep-sided, limestone or cemented sand dunes, although a few low sandy islands also occur. Most support scrub (6),

succulent or mixed beach vegetation (2,3), although the larger ones have shrubs (4) and occasionally trees. The cays south of this chain (east of Puerto Rico) and around Culebra Island are variable, most being either rocky with a beach, or sandy. The larger ones support xeric forest (9), the smaller ones only succulent or mixed beach vegetation (2,3) or scrub (6).

The Virgin Islands, St. John, Tortola and St. Croix have mesic forest plus all other categories (1 - 12). The other principal islands except Anegada, as well as a few somewhat smaller ones such as Guana, Greater Caminoe, Peter, Norman, and Greater Thatch have xeric forest. The remaining cays and small islands plus Anegada are variable. However, few support vegetation more lush than scrub (6), or at most limited areas of xeric forest (9). The available climate and soil data, corroborated by conversation with older inhabitants, indicate that at one time forest was more extensive on both the larger and the smaller islands. Apparently it has been decimated by charcoal burners, cultivators, and feral animals, a widespread phenomenon throughout the Caribbean as indeed in the tropics generally.

GEOLOGY

Rosen (1975) has reviewed the previous history of the Caribbean. Although there is not unanimity among authorities on the topic, he felt that the most reasonable synthesis of the geologic and biogeographic data was the following sequence of events. In the late Mesozoic when South America was separating from Africa, a subduction zone consuming the eastern Pacific sea floor bordered the western coast of both North and South America and the area between them, the latter consisting of a volcanic archipelago, the Proto-Antilles. Subsequently, separate North and South American plates arose by the formation of two decoupling faults on either side of the Proto-Antilles. With the continued relative westward drift of the North American and South American plates, the Proto-Antillean region became displaced eastward towards its present relative position; a new fault zone occurred which separated the Proto-Antilles into two subregions which subsequently became the Greater Antilles and Lesser Antilles. With the continued westward movement of the major American continents, further faulting occurred breaking up the Central American region into an archipelago which subsequently joined to form the present day isthmus; the Caribbean islands aligned themselves into their present relative positions.

If this model is correct, the Greater Antilles have been an archipelago for a long time, contrary to previous opinion that the major Antillean islands were broadly connected (Schuchert 1935). Connections between adjacent banks were rare, the Puerto Rican one never having been connected to the nearest one to the east (St. Maarten) (Butterlin 1956). If it was ever connected to Hispaniola, it lost the connection in the Pliocene or earlier (Mitchell 1954).

The Puerto Rican Bank (Puerto Rico, its outlying islands, the American and British Virgin Islands) resulted from vulcanization in the Cretaceous (Meyerhoff 1933) and became emergent during orogenic movements in the late Eocene (Butterlin 1956). In contrast to the paucity of connections between banks, connections of islands within the Puerto Rican Bank have been extensive and recent. Heatwole and MacKenzie (1967) have shown that the principal islands of the Virgin group (except St. Croix) lost their connection with each other and with Puerto Rico only about 8,000-10,000 years ago, due to eustatic rise in sea level. Culebra lost its connection with Puerto Rico and the Virgins at the same time, although Vieques, Caja de Muertos, and many small cays remained connected to Puerto Rico until about 6,000 years ago. The smaller islands around the principal Virgins were separated from the latter at various times before 8,000-10,000 B.P.

By contrast, Mona, Monito, Desecheo and St. Croix have been isolated much longer, not having been connected to any other islands since at least the Pliocene, if then.

A number of islands were present at various times which have since submerged.

ISLAND AND COASTLINE FORMS

The larger islands are of volcanic origin and consist mainly of igneous and metamorphic rock with quite steep topography. Puerto Rico has, in addition, an extensive northern and a smaller southern strip of cenozoic limestone which has been extensively eroded, giving rise to characteristic low, blocky, vertical-sided hills with many caves. Mona, Monito and the higher islands to the northeast of Puerto Rico are of similar origin, while Anegada is a low, flat limestone shelf, contrasting markedly with all the other islands of the Puerto Rican bank save for a few small cays.

Form of the smaller islands varies considerably, and ranges from low, sandy cays with gently sloping beaches to mushroom-shaped ones surrounded by vertical cliffs undercut at the base by wave action. Many islands have a great proportion of the coastline made up of rock which is neither vertical cliff, nor beach. We termed this "intermediate type". A final coastline type consisted of mangrove swamp. Most large islands have several coastline types, including beach, undercut cliffs, and intermediate type.

METHOD OF SURVEY

Each island surveyed was described as to its vegetation (see above), geological type, soil, presence or absence of standing water, maximum height, area, nature of shoreline, and proportion of each type of coast, proportion surrounded by barrier reef, distance to nearest other land-mass on the Puerto Rican shelf in each of 4 quadrants, degree of

disturbance by humans and time of isolation from other land masses.

Proportions of various shoreline types were obtained by measuring the perimeter on a map or aerial photograph with a Radix map measurer, keeping values for each coastline type separate in accordance with observations made while on the island. Percentages of each type were then calculated. Island areas were obtained either from the literature, from maps using a planimeter, or by direct measurement. Maximum height was obtained from topographic maps, or in the case of small cays by direct estimation or measurement. The other information was obtained by direct observation supplemented by maps, aerial photographs, nautical charts, conversations with inhabitants of various islands, and the literature.

On every island visited, each of the above-defined vegetation categories which was present was searched for the following group of animals; terrestrial isopods, centipedes, millipedes, pseudoscorpions, amblypigids (= phrynichids or tailless whip scorpions), scorpions, spiders, ants, *Drosophila*, land snails, amphibians and reptiles; other groups provided supplementary information on certain aspects. We were opportunistic in that ease of sampling and the probability of obtaining adequate samples in a relatively short time was a consideration in our choice of groups. However, the animal groups we used were chosen to include both eurytopic and stenotopic forms, those with weak and those with strong dispersal powers, and groups with a wide range of suspected evolutionary rates. Specialists in various groups identified (or are in the process of identifying) our material and advised on techniques which would provide as complete a representation of an island's fauna as possible. These methods included use of (1) Tullgren funnel extraction of litter samples transported to the laboratory in plastic bags, (2) sweeping vegetation with an insect net, (3) beating vegetation over a white sheet, (4) examining litter on a white sheet, (5) setting out bait (mixed fruits for *Drosophila*, sugar and tuna for ants, etc.), (6) shooting or noosing (reptiles), (7) careful search of the surface of the ground and vegetation and under rocks and other objects, and (8) breaking open twigs, old termite nests, logs, and other debris.

All data were stored on computer cards. Statistical treatment is discussed later in appropriate papers, as are other special methods used for individual parts of the project. Biogeographic and taxonomic treatments will be published by the various specialists that have received material. The appendices list the results for some groups for which a number of identifications are now available.

SPECIAL NOTES

The island of Sail Rock (Appendix I) requires special mention. It is a mass of rock rising 38 m (125 ft) precipitously out of the sea. It is about 100 m in diameter. The cliffs around it are vertical or nearly vertical and are undercut at the base. It is unusual in that

it completely lacks terrestrial vascular plants and hence no local autotrophic energy base for the surprisingly large number of terrestrial animals. Indeed, the only terrestrial plants observed at all was a green alga in one crevice on the north side. A few individuals of a marine plants, *Sargassum*, collected by sea birds or material was present but did not appear to have any terrestrial animals associated with it or feeding upon it.

We visited the island in May 1966, scaled the cliffs and made an intensive search for organisms on the top.

Numerous cracks and crevices occur in the rock on top, and on the few flat, or nearly flat areas, there are some loose boulders and stones. From these places we collected species of terrestrial vertebrates and one vertebrate (a gekkonid lizard, *Sphaerodactylus macrolepis macrolepis*); many of the species were quite abundant. By far the most abundant arthropod present was a terrestrial isopod. It occurred in surprisingly dense populations and probably served as the basis for much of the rest of the terrestrial food chain which consisted largely of predators, there was 1 species each of centipede, tailless whip scorpion (amblypigid = phrynichid), scorpion and spider. There was in addition one species of ant, several other species of insects, and a land crab. Unfortunately none of the invertebrates were identified to species as our collection was lost in the mail when sent to specialists for identification and we have not had opportunity to visit the island again. However, sufficient is known about the genuine feeding habits of some of the groups to comment on the probable trophic relations.

The top of the island was used extensively by sea birds for nesting and their excrement literally covers the island, giving it a white-washed appearance. These birds feed on fish and hence it is probable that they serve as transfer organisms (Heatwole 1975) obtaining energy from the marine community and depositing a food source for the terrestrial community on the island in the form of guano and on occasions as carrion (dead adults or chicks) or broken eggs. The guano is believed to be the most important source as is carrion was observed and the only species likely to be scavengers that were present was the land crab and possibly the ant. The undercut nature of the island and its height would make work up of marine carrion unlikely. Isopods generally feed on detritus or other finely divided organic matter and we suspect that it fed on guano and in turn was preyed upon by the predatory invertebrates. The larger predators such as scorpion, whip scorpion, and lizards probably eat isopods and some of the invertebrates that prey on isopods. None of the lizards we collected had prey in their stomachs. However, we did obtain three recognizable items from the section of one animal. There were remains of an ant, the head of an insect larva, and surprisingly, parts of a species not otherwise known from the island, a homopteran. The last is a plant feeder and must represent a waif arriving aerially (the nearest vegetated land mass, Culebra Island is 14 km away).

In summary, the probable trophic relations are (1) a transfer of marine-derived energy via sea birds in the form of guano and carrion, (2) its utilization by isopods which (3) serve as prey for a variety of predators, (4) leading to secondary predators. The endogenous prey is probably supplemented by (5) aerial waifs. Complete dependence of an insular terrestrial community upon exogenous, marine-derived energy, although unusual, is not unique. Heatwole (1975) reports communities of several terrestrial species (including predators) on vegetation-free sand cays in the Coral Sea.

The source of the terrestrial fauna on Sail Rock is problematic. Sail Rock became isolated from the once continuous land mass of Greater Puerto Rico (about 8,000 years B.P.) (Heatwole and MacKenzie 1967), and it seems unlikely that the resident species could have maintained themselves on such a small barren island. On the whole the undercut nature of the island's base would suggest that at present flotsam transport would be unlikely and the flightless nature of many of the resident species would militate against aerial transport. The difficulty of access to the island would make human transport unlikely, although there is an automatic light house on top which is periodically serviced. Introduction of so many species by this means, however, seems unlikely.

From the above, it is clear that Sail Rock is especially interesting from the standpoints of island biogeography and community ecology. It would warrant quantitative study by someone in a position to carry out a long-term observation there.

DISCUSSION

The brief description of the general ecology of the archipelago presented above provides a summary of local conditions during the 8-year period in which data were collected. Many ecological characteristics are, however, in the process of rapid change, largely through human influence. An assessment of the nature of such changes is requisite for placing the present study in perspective and for evaluation of future data.

In pre-Columbian times a succession of cultures occurred in the area, especially on the larger islands. However, even those as small as Culebra (about 14 x 6 kms) had at least semi-resident populations, a midden containing various artifacts was found on this island during one of our field trips. Some species, such as useful plants and the edible iguana, may possibly owe their distribution in part to transport by these early residents. In post-Columbian times, man's effect was accelerated through additional clearing of land and establishment of an European-type culture. Domestic animals and a variety of ornamental and edible plants were purposefully introduced as well as various weeds, rodents, insects and other involuntarily-transported species. Feral cats and especially rats have possibly had an adverse effect on the now rare and endangered Puerto Rican

parrot (*Amazona v. vittata*) through depredation of nests (Rodriguez-Vidal 1959). The mongoose was introduced in order to control rodents (unsuccessfully). The role of the mongoose in the decline and extinction of West Indian native fauna may not be as great as is sometimes attributed to it, but it is almost certainly responsible for local extinction of some lizards, snakes and ground-nesting birds (see Barbour 1930, Heatwole and Torres 1967, Philibosian and Ruibal 1971).

The cane toad (*Bufo marinus*) was brought to Puerto Rico to control insect pests of sugar cane in 1920 (Bartlett 1949) and is now abundant on various islands. Cayo Santiago has had a feral band of rhesus monkeys for a number of years. Recently, introduction of some of them into several additional islands was made. These populations will undoubtedly have an ecological effect.

Goats and sheep are perhaps the most destructive of any introduced species, and there are probably few islands in the archipelago which have not been disturbed to some extent by these animals at some time or other. The early custom of releasing goats and other domestic ungulates on small islands and cays for later use by mariners was apparently common (Davis 1971). Mona and Desecheo Islands still maintain local populations originating in this way; the former island serves as a reserve for sportsmen to hunt goats and feral pigs. Many of the cays in the Virgin Islands have goat herds which belong to residents from larger islands and from which individuals are periodically killed for meat. Perhaps the island most affected by feral animals is Salt Island, B.V.I., in which the greater part of the vegetation has been reduced to a low, open strand of *Croton rigidus* and *C. astroites*, species unpalatable even to goats. Except for creeping *Opuntia repens*, the spaces between *Croton* bushes are nearly devoid of other vegetation, and goats have been observed gleaning the tiny grasses and annuals which do appear.

On Salt Island at least, free-roaming sheep and cattle also played a role in decimating once-considerable grassy areas (Mrs. Beatrice Smith, personal communication). These animals died out, since they cannot subsist on a diet of woody dicots as can goats. Observations on exclosures over a three-year period (Byer, in preparation) suggest that once ground cover is eliminated, re-establishment of woody plants is retarded even in the absence of goats. Possibly increased run-off either washes seeds away directly or removes organic matter necessary for their germination.

The degree of disturbance to a small island seems to be related to its geomorphologic type. Monito, which has steep sides undercut at the base, is relatively inaccessible and has probably been visited by humans only a few times (Rolle *et al.* 1964). The same is true of a number of the small islands in the chain just northeast of Puerto Rico. The latter, however, were used for strafing practice during World War II and remnants of shells can still be found embedded in rock on the top of some. Others of the relatively inaccessible steep-sided islands (e.g. Sail Rock) constitute shipping dangers and have light-

houses or other navigational aids which must be periodically serviced.

Many of the small accessible islands are frequently visited for short periods by fishermen who camp on the beach but otherwise have a minimal effect. Some islands containing large colonies of nesting sea birds are periodically visited by egg gatherers (e.g. Frenchcap Cay). A number of the more accessible islands have people living on them, even some as small as Ramos Island ($< \frac{1}{2}$ km in greatest diameter). Lobos Island (slightly more than $\frac{1}{2}$ km in greatest diameter) has a tourist hotel, and Isleta Marine serves as a yacht basin. Most islands with some beach and larger than 1 km in greatest diameter are inhabited either permanently or seasonally. Some inhabited islands show almost no disturbance by their residents (e.g. Guana Island); most however, are clearly modified by agricultural or other practices. Cayo Luis Peña and part of Culebra Island are used for bombing and naval gunnery practice. During World War II, Desecheo was used for bombing practice and bomb fragments can still be found on various parts of the island.

Human effects have accelerated greatly during our study. On many small uninhabited islands in the beginning of the study one was reminded of the proximity of human populations only by the large numbers of bottles, light bulbs, shoes, etc. encountered in the beach drift. Most, however, especially if currently goat-free, appeared in a relatively natural state. Various such islands close to Puerto Rico, were selected for detailed, long-term study (e.g. Cayo Ahogado and Palominos). It was fortunate that our study was initiated as early as it was because today one would have to select less accessible islands in order to carry out such studies. Those near Puerto Rico with good anchorage for small craft are now visited by large numbers of weekend excursionists, who have turned the cays into veritable garbage and trash dumps and have cut woody vegetation for campfires and tent supports.

It appears that the small, inhabited islands whose owners discourage trespassing are likely to retain some similarity to their natural state, whereas uninhabited, public ones are already being rapidly destroyed.

The larger islands also show an alarming degree of human disturbances to natural communities. For example, in a study contracted by the Puerto Rican government, Heatwole (1970) found that that island had lost a mean of 1.7% of its coverage of mangrove per decade between 1930 and the mid-1960's. Between 1965 and 1970, large tracts were lost, some swamps dying completely. Industrial pollution and interference with drainage patterns by construction activities, dredging, and filling contributed to their demise. Proposed touristic development in the Vacía Talega area will probably eliminate much of Puerto Rico's best remaining mangrove, and is already flooding the island's largest stand of *Avicennia*, near Boguerón, with fresh water in order to convert it into a *Typha* marsh to be used for waterfowl hunting. The flooding was undertaken because all sizeable natural

fresh-water marshes, once thought valueless, had been eliminated some time in the past by agricultural development.

The destruction of habitat with increasing levels of human population is of course, not a problem unique to islands. However, there may be unique aspects arising from insularity. It would appear that three major tasks face island ecologists, (1) detailed study of the functioning of relatively undisturbed insular ecosystems while such are still available, (2) the assessment of the effect of human pressure on such ecosystems, and (3) recommending practices for use of small islands in ways that will not result in their destruction and loss to the human population. The series, to which this paper represents the introduction, concentrates largely on the first of these tasks.

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TABLE 1. TEMPERATURES (MEANS AND RANGES) IN DIFFERENT MICRO-HABITATS ON CAYO AHOGADO, MARCH 16-21, 1966.

DATE	Rh %	T _{BB}	AIR TEMPERATURES			SOIL TEMPERATURES			TEMPERATURES AT A CLUMP OF VEGETATION				
			1 cm	15 cm	1 m	5 cm deep	1 cm deep	Surface	5 cm in soil	1 cm in soil	Soil Surface under Clump	Surface of Vegetation	Center of Clump
16*	--	24.7	25.1	25.2	25.3	25.6	24.1	23.9	24.7	24.4	24.5	24.9	24.9
		24.2-25.5	24.7-25.7	24.8-25.9	24.9-25.9	24.8-27.1	23.4-25.5	23.3-25.0	24.5-25.0	24.0-25.1	24.0-25.3	24.5-25.5	24.5-25.5
17	74	33.5	27.5	27.3	26.6	28.0	29.3	30.4	25.8	26.4	27.6	27.0	27.3
	62-93	24.8-39.0	24.9-30.6	25.2-29.5	25.2-27.7	23.7-30.7	23.6-33.8	24.2-37.9	24.1-26.9	24.8-28.2	25.4-29.9	25.3-28.5	25.3-29.5
18	73	32.1	27.4	26.7	26.3	27.6	28.9	29.9	26.6	27.4	28.0	26.7	27.6
	63-95	22.2-41.1	22.9-32.2	22.5-30.1	22.3-28.4	23.3-31.3	21.5-35.5	21.3-38.2	23.2-29.2	23.2-31.4	22.5-33.2	24.7-29.3	22.2-32.2
19	78	24.1	23.7	23.8	23.6	23.8	22.9	22.8	22.9	22.6	22.9	23.8	23.7
	73-86	22.5-26.9	22.7-25.4	22.3-24.5	22.3-25.2	23.3-24.3	22.0-24.2	21.7-24.5	22.5-23.2	22.0-23.3	22.0-24.0	22.3-25.1	22.4-25.1
20	70	32.0	25.8	25.6	25.2	25.7	27.1	27.3	23.9	24.4	25.2	25.6	25.7
	60-82	23.7-40.8	23.5-28.3	23.4-27.5	23.7-26.7	22.0-28.5	21.4-32.7	21.9-32.6	22.0-25.8	21.9-26.4	22.5-27.5	23.8-27.0	23.7-27.3
21**	87	24.1	23.2	23.5	23.9	23.1	21.9	22.2	----	----	----	----	----
	86-88	22.7-25.5	23.1-23.3	23.1-23.8	23.4-24.4	22.6-23.5	21.7-22.0	21.7-22.7	----	----	----	----	----

* Late evening and night only.

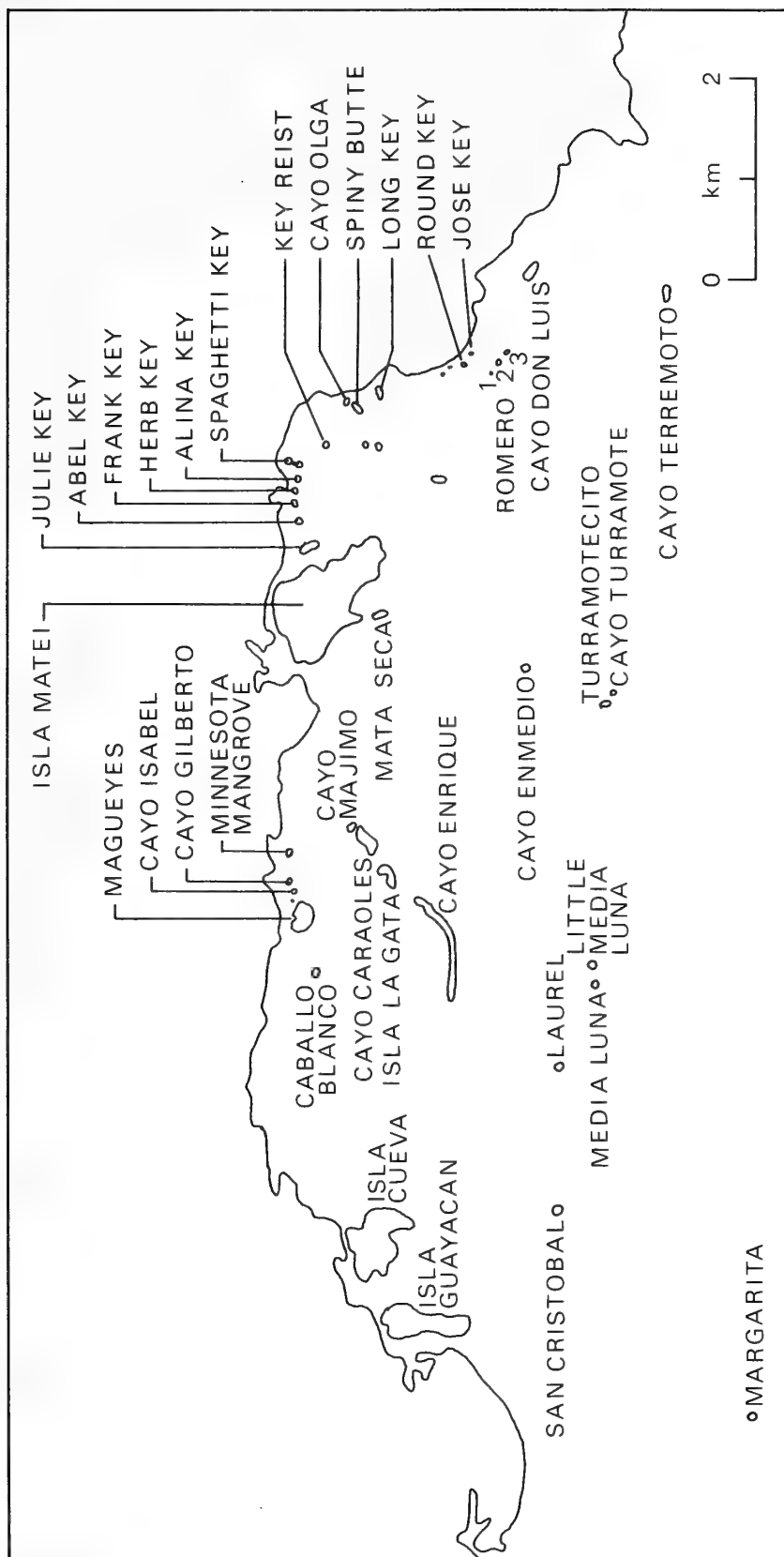
** Early morning only.

Table 2 cont'd.

	1	2	3	4	5	6	7	8	9	10	11	12
East Geniquí	10	5			10	50			25			
East Seal Dog	x			x		x	x					
Eustatia	2		1		15	50	1		30		1	
Fallen Jerusalem						x	x		x			x
Frank Key								100				
Frenchman's Cap (French Cap Key)	x			60	37	3						
Frenchman's Cay	x				97				3			
George Dog			2		30	38	x		30			
Ginger Island	x					52	3		45			
Grant Rock	20	80										
Green Cay (Near St. Croix)	x		x	x		x						
Guana	x		x	x		x			x		x	
Gusano	x		x	x								
Herb Key								100				
Hicacos	x		x		x	x	x		x			
Island O								100				
Island Q	40	30						30				
Island R								100				
Isleta Marina	x		x								x	x
José Key								100				
Julie Key								100				
Key Reist								100				
Konyokí	20						60	20				
La Gata (Isla La Gata)	x							x				
Laurel	10							90				
Levin's Rock	x			x								
Little Hans Lollick	x	x	x			50	x	x	50		x	
Little Saba Island					25	75	x					
Little Tobago	x				70				30			
Long Key								100				
Magueyes		x			20	70		x	10			x
Mangrove Key		50						50				
Marina Cay	x	x		x		x	x					x
Mata Seca								100				
Media Luna	95							5				
Minnesota Mangrove								100				
Mona	x		x			x	x		x			
Monito	x					x						
Mosquito Island			4		5		6		80			5
Necker Island	5		x			70	x		25			
Norman Island	2		3			23	2		60	10		
Outer Caracol (Cavo Caracoles)	x	x						x				
Palominitos	20		20			55			5			
Palominos	x				10	90						x

Table 2 cont'd.

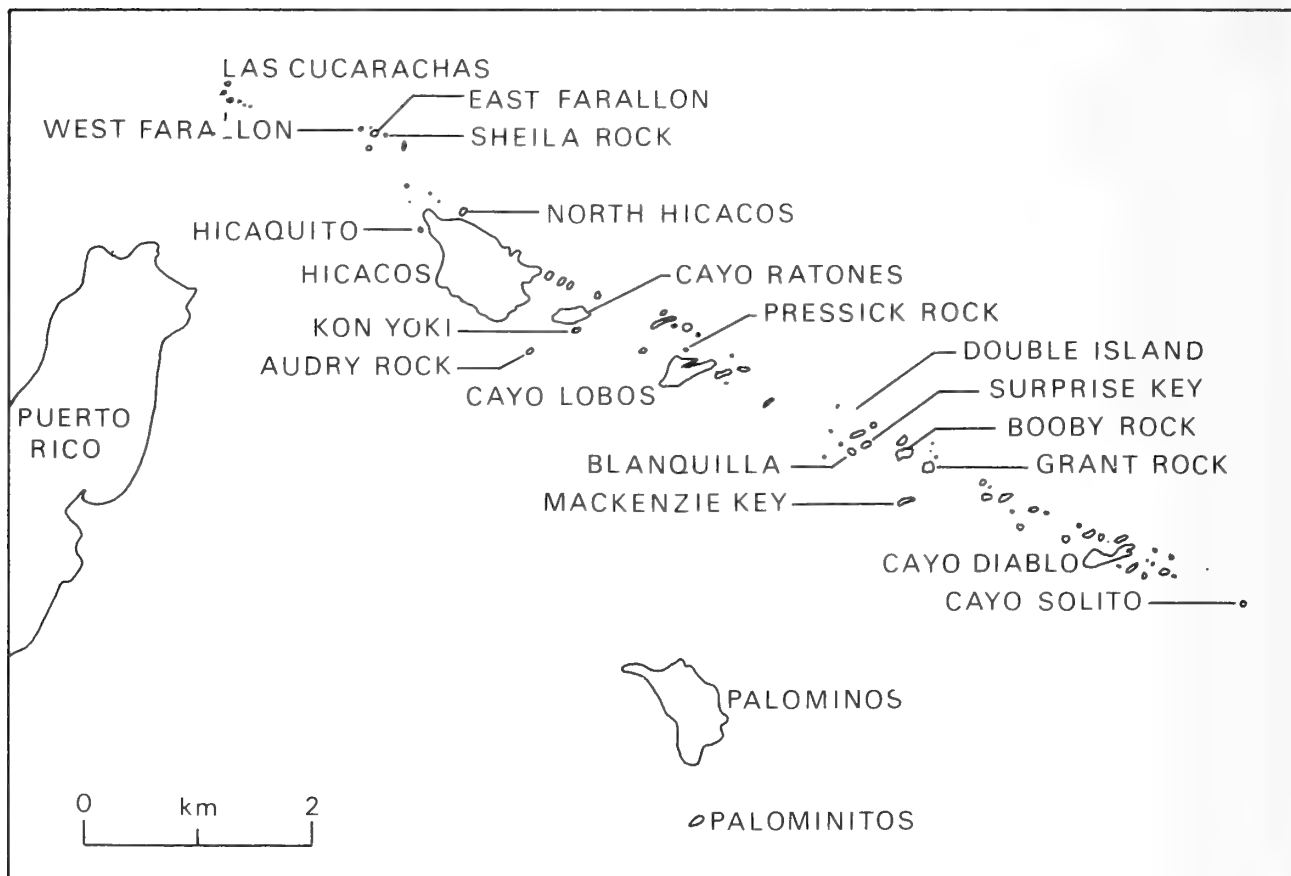
	1	2	3	4	5	6	7	8	9	10	11	12
Pelican Key	90			5		5						
Peter Island	x	x	x	x	x	x	x	x	x			
Platillo	x			x		x	x					
Prickly Pear	x				70				30			
Protestant Key	x			x			x	x			x	x
Puerto Rico	x	x	x	x	x	x	x	x	x	x	x	x
Ramos	x		x			x	x	x			x	x
Ratones (Cayo Ratones)	x		x		x	80	6	4	10		x	
Romero II								100				
Romero III								100				
Round Key								100				
Sail Rock	100											
Salt Island	x		x			80	5	x	10		5	x
San Cristobal	82	15						3				
Sheila Rock	95	5										
Solito	75	25										
(Cayo Solito)												
Spaghetti Key								100				
Spiny Butte						65		5	30			
St. Croix	x	x	x	x	x	x	x	x	x	x	x	x
St. John	x	x	x	x	x	x	x	x	x	x	x	x
St. Thomas	x	x	x	x	x	x	x	x	x		x	x
Surprise Key	20	50	15		15							
Tortola	x	x	x		x	x	x	x	x	x	x	x
Turramote	25	50						25				
Vieques	x	x	x	x	x	x	x	x	x		x	x
Villa del Mar					90		5	5				
Virgin Gorda	x	x	x	x	x	x	x	x	x		x	x
Watson Rock	90		x	5	5							
West Dog					x	x	x		x			
West Farallón	95	5										
West Seal Dog	x				25	60	15					

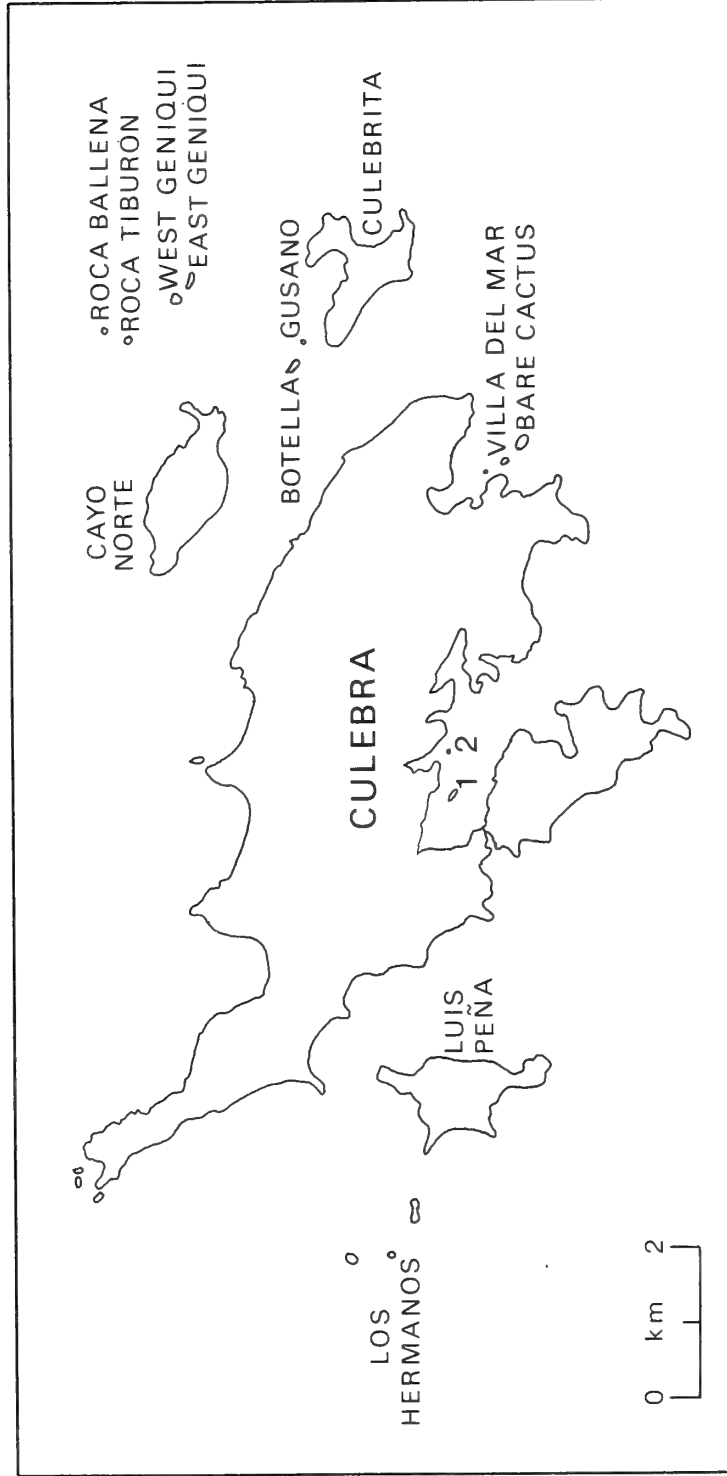
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B.

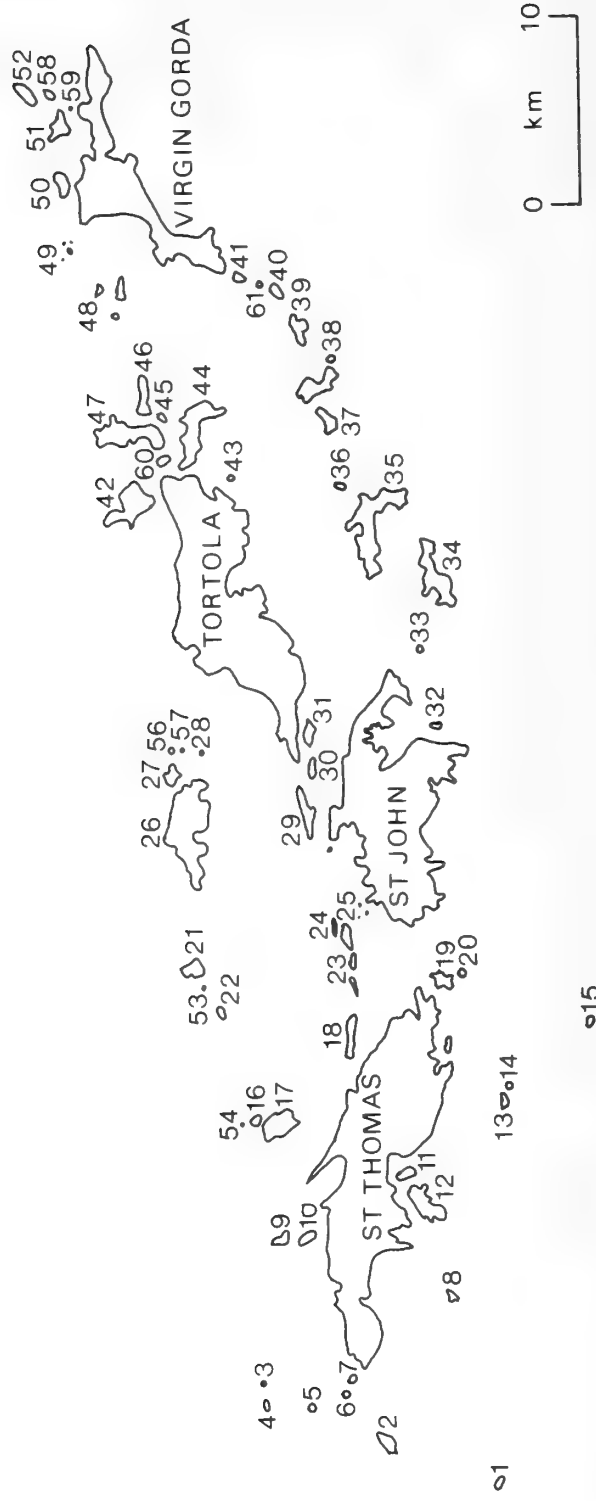


C.





D.



Appendix I. Maps of small islands on the Puerto Rican Bank. Inconsistency in use of "cay" and "key" reflects differences between the American and British Virgin Islands in the way the word is spelled. We prefer the former and use it unless "key" is part of the proper name of an island.

- A. Cays in the La Parguera region of Puerto Rico (enlargement of rectangle A in Figure 1).
- B. Cays immediately east of Puerto Rico (enlargement of rectangle B in Figure 1). 1. Levin's Rock
- C. Cays between Puerto Rico and Culebra Island (enlargement of rectangle C in Figure 1).
- D. Culebra Island and its surrounding cays (enlargement of rectangle D in Figure 1). 1. Chicken Island, 2. Mangrove Key.
- E. The islands and cays of the American and British Virgin Islands, except for St. Croix and its nearby islets (enlargement of rectangle E in Figure 1).

- | | |
|---------------------------------------|--------------------------------|
| 1. Sail Rock | 30. Little Thatch Island |
| 2. Savanna Island | 31. Frenchman's Key |
| 3. Cricket Rock | 32. Leduck Island |
| 4. Cockroach Island (near St. Thomas) | 33. Flannigan Island |
| 5. Dutchman's Cap | 34. Norman Island |
| 6. Salt Cay | 35. Peter Island |
| 7. West Cay | 36. Dead Man's Chest |
| 8. Little Saba Island | 37. Salt Island |
| 9. Outer Brass Island | 38. Cooper Island |
| 10. Inner Brass Island | 39. Ginger Island |
| 11. Hassel Island | 40. Round Rock |
| 12. Water Island | 41. Fallen Jerusalem |
| 13. Buck Island (near St. Thomas) | 42. Guana Island |
| 14. Capella Island | 43. Buck Island (near Tortola) |
| 15. Frenchman's Cap (French Cap Key) | 44. Beef Island |
| 16. Little Hans Lollick | 45. Marina Cay |
| 17. Big Hans Lollick | 46. Scrub Island |
| 18. Thatch Key | 47. Greater Camanoë |
| 19. Greater St. James | 48. The Dog Islands: George |
| 20. Little St. James | Dog, West Dog, Great Dog |
| 21. Big Tobago | and Big Cockroach (near |
| 22. Little Tobago | Virgin Gorda) |
| 23. Mingo Key | 49. Seal Dogs: East Seal Dog |
| 24. Congo Key | and West Seal Dog |
| 25. Lovango Key | 50. Mosquito Island |
| 26. Jost van Dyke | 51. Prickly Pear |
| 27. Little Jost van Dyke | 52. Necker Island |
| 28. Sandy Key | 53. Watson Rock |
| 29. Great Thatch Island | 54. Pelican Key |

55. A series of tiny cays, R, O, Q and Byer Bache
56. Green Cay (Jost van Dyke)
57. Sandy Spit
58. Eustatia
59. Saba Rock
60. Little Camanoe
61. Broken Jerusalem

Appendix II. Floral lists from some small islands and cays in the Puerto Rican and Virgin Island area. These should be considered as plant records rather than complete floras except for those islands marked with an (*) for which attempts were made to collect all species. Major islands not included; for treatment of their flora and vegetation see Britton and Wilson (1923-30), Gleason and Cook (1927), Little and Wadsworth (1964) and Dansereau (1966). Byer has a long-term, comprehensive study of the flora of small islands of this region in progress.

ANEGADA

See D'Arcy (1971, 1975)

CAYO AHOGADO

See Heatwole and Levins (1973)

BIG COCKROACH

Cephalocereus royeri
Opuntia dillenii

CAÑA AZUL *

Avicennia nitida
Rhizophora mangle

BIG HANS LOLICK

Thrinax argentea
Piscidia piscipula
Citharexylum fruticosum
Torrubia fragrans (?)
Pithecellobium unguis-cati
Croton astroites
Agave missionum
Vigna marina
Coccoloba uvifera
Hippomane mancinella
Bursera simarouba
Capparis indica (?)

CAYO BATATA

See Heatwole, Sade and Hildreth (1963)

CAYO ENMEDIO *

Sesuvium portulacastrum

CAYO ENRIQUE *

Sesuvium portulacastrum

CAYO MAJIMO *

Sesuvium portulacastrum

CAYO SANTIAGO

See Heatwole, Sade and Hildreth (1963)

BIG TOBAGO

Conocarpus erecta
Croton astroites
Bulbostylis vestita
Agave missionum
Cephalocereus royeri
Tabebuia heterophylla
Pithecellobium unguis-cati
Torrubia fragrans
Bursera simarouba
Opuntia repens

CAYO TURREMOTECITO *

Sesuvium portulacastrum

COOPER ISLAND

Bursera simarouba
Cakile lanceolata
Carica papaya
Coccoloba uvifera
Cocos nucifera
Croton astroites
Euphorbia buxifolia
Musa sp.
Sporobolus virginicus

DOUBLE KEY *

Sesuvium portulacastrum

DEAD MAN'S CHEST

Coccoloba uvifera
Croton astroites
Croton sp.
Sesuvium portulacastrum
Sporobolus virginicus

EAST FARALLON *

Sesuvium portulacastrum

EUSTATIA

Bursera simarouba
Cakile lanceolata
Cocos nucifera
Croton astroites
Hippomane mancinella
Sporobolus virginicus

FALLEN JERUSALEM

Bursera simarouba
Coccoloba uvifera
Croton astroites
Tabebuia heterophylla

FRENCHCAP CAY

Canavalia maritima
Clerodendron aculeatum
Cyperus planifolius
Ficus laevigata
Hippomane mancinella
Mollugo verticillata
Portulaca grandiflora

GEORGE DOG ISLAND

Bursera simarouba
Coccoloba uvifera

GINGER ISLAND

Avicennia nitida
Bursera simarouba
Croton astroites
Croton rigidus
Pisonia subcordata

HICACOS

See Britton (1924)

ISLAND O *

Rhizophora mangle

ISLAND R *

Rhizophora mangle

ISLAND Q *

Borrighia arborescens
Laguncularia racemosa
Rhizophora mangle
Salicornia ambigua
Sesuvium portulacastrum

LEVINS ROCK *

Canavalia maritima
Erithralis fruticosa
Paspalum glabrum

LITTLE HANS LOLLICK

Bursera simarouba
Cephalocereus royeri
Coccoloba uvifera
Croton astroites
Croton discolor
Hippomane mancinella
Jacquinia barbasco
Opuntia dillenii
Opuntia repens
Opuntia rubescens
Pithecellobium unguis-cati
Rivina humilis
Sporobolus virginicus
Thrinax argentea
Torrubia fragrans

LITTLE SABA

Cephalocereus royeri
Conocarpus erecta
Rhizophora mangle

LITTLE TOBAGO

Agave missionum
Bursera simarouba
Cephalocereus royeri
Croton astroites
Jacquemontia jamaicensis
Lantana involucrata
Opuntia dillenii
Pithecellobium unguis-cati
Sporobolus virginicus
Torrubia fragrans
Vigna marina

MOSQUITO ISLAND

Bursera simarouba
Carica papaya
Coccoloba uvifera
Croton astroites
Hippomane mancinella
Sporobolus virginicus
Tabebuia heterophylla
Torrubia fragrans (?)

NECKER

Bursera simarouba
Cactus intortus
Cephalocereus royeri
Coccoloba uvifera
Croton astroites
Croton rigidus
Guilandia crista

NORMAN ISLAND

Amaranthus dubius
Atriplex sp.
Bursera simarouba
Capparis flexuosa
Coccoloba uvifera
Conocarpus erecta
Croton astroites
Euphorbia sp.
Laguncularia racemosa
Pisonia albida
Sporobolus virginicus
Tamarindus indica

PALOMINITOS *

Borrichia arborescens
Cakile lanceolata
Canavalia maritima
Cassytha filiformis
Cenchrus echinata
Cenchrus pauciflorus
Coccoloba uvifera
Conocarpus erecta
Cyperus planifolius
Erethralis fruticosa
Ermodia littoralis
Euphorbia buxifolia
Lantana involucrata
Melanthera nivea
Scaevola plumeri
Sesuvium portulacastrum
Suriana maritima
Vigna marina
 3 unidentified

PELICAN KEY

Capparis flexuosa
Conocarpus erecta
Laguncularia racemosa
 (disappeared again before
 June 1968)
Opuntia repens
Portulaca oleracea
Sporobolus virginicus

PLATILLO

Coccoloba uvifera

PRICKLY PEAR

Agave missionum
Bursera simarouba

RATONES

Coccoloba uvifera

SAIL ROCK *

Barren

SALT ISLAND

Cocos nucifera
Croton astroites

SAN CRISTOBAL *

Avicennia nitida
Laguncularia racemosa
Philoxerus vermicularis
Rhizophora mangle
Sesuvium portulacastrum

SHEILA ROCK *

Sesuvium portulacastrum

SOLITO *

Sesuvium portulacastrum

SPINY BUTTE *

Acuan virgatum
Ayenia pusilla
Boerhaavia erecta
Bursera simarouba
Capparis flexuosa
Commelina elegans
Cordia angustifolia
Croton discolor
Croton humilis
Euphorbia berteriana
Hibiscus brasiliensis
Hippomane mancinella
Lantana involucrata
Leptocereus quadricostatus
Molluchia tomentosa
Opuntia dillenii
Panicum maximum
Pectis linifolia
Pithecellobium unguis-cati
Portulaca pilosa
Pteramnus labialis
Rauwolfia lamarckii
Rhizophora mangle
Ruellia tuberosa
Sida glabra
Sida procumbens
Stigmaphyllon lingulatum
 3 unidentified

TURREMOTO (CORRAL)

Avicennia nitida
Laguncularia racemosa

WEST DOG ISLAND

Coccoloba uvifera
Conocarpus erecta
Croton rigidus

WEST FARALLON *

Sesuvium portulacastrum

WEST SEAL DOG

Coccoloba uvifera

Appendix III. Reptiles and Amphibians of the Puerto Rico -
Virgin Island Archipelago

The islands from which each species was collected are listed first, followed by a listing of all of the herpetofauna for each island. An attempt was made to do a complete survey on each island. These lists are based on our own collections, those of various museums, literature records up to 1970 which we have not verified (*), and our own sight records (**). They do not include the records obtained by other investigators after 1972, and whose collections we have not seen. Some of these later collections add species for islands we have surveyed and present records from a number of islands we did not visit. A complete listing of the known insular distributions of the Puerto Rican - Virgin Island species can be obtained from a combination of the present paper, and the publications of Schwartz and Thomas (1975), Philibosian and Yntema (1976, in press) and Maclean et al. (1977). In our list, island names in parentheses indicate that the species in question was recorded from that island but probably does not occur there as a permanently established breeding population. This list corrects that of Schwartz and Thomas (1975) for *Anolis cristatellus cristatellus* and *Anolis cristatellus wileyae* in line with the taxonomic assessment of Heatwole (1976b).

Schwartz and Thomas indicated *A. c. cristatellus* to inhabit many islands east of Puerto Rico, which are in fact inhabited by *A. c. wileyae* instead.

Distribution of Species

LIZARDS

Iguanidae

Anolis acutus

Buck Island (near St. Croix)	Protestant Key
Green Key (near St. Croix)	St. Croix

Anolis cooki

Caja de Muertos	Puerto Rico
-----------------	-------------

Anolis cristatellus cristatellus

Algodones	Isleta Marina ¹
Caja de Muertos	Long Island
Cardona Key	Magueyes Island
(Cayo Ahogado)	Platillo
Cayo Batata	Puerto Rico
Cayo Santiago	Ramos

¹ Also hybrids between *A. c. cristatellus* and *A. c. wileyae*.

Anolis cristatellus wileyae

Algodones	Diablo
Anegada	* Dog Island
Bare Cactus Island	* Dutchman's Cap
Beef Island (near Tortola)	East Seal Dog
Blanquilla	Eustatia
Booby Hatch	Fallen Jerusalem
Botella Island	George Dog Island
* Buck Island	Ginger Island
(near St. Thomas)	
Cabeza de Perro	Grant Rock
Cayo Lobos	* Great Dog Island
Cayo Norte	Greater Camanoe
Cayo Ratones (near Hicacos)	Greater Thatch Island
Chicken Island	Green Cay (near Tortola)
Cockroach Island	Guana Island
(near St. Thomas)	
Cooper Island	Hans Lollick
Congo Cay	* Hassel Island
Culebra	Hicacos
Culebrita	* Inner Brass Island
Dead Man's Chest	Isla Cabras (near Roosevelt
	Rds P.R.)
Isleta Marina	Ramos
Konyokí	* St. James
Little Camanoe	St. John
Little Hans Lollick	St. Thomas
Little Jost van Dyke	Salt Island
Little Saba (near St. Thomas)	* Salt Key
* Little St. James	Sandy Cay (near Tortola)
Little Tobago	Sandy Spit
* Lovango Key	* Savanna Island
Marina Cay	Scrub Island
Mosquito Island	Surprise Key
Norman Island	Tobago
Necker Island	Tortola
Palominos	Vieques
Palominos	Villa del Mar
Peter Island	Virgin Gorda
Piñeros	* Water Island
Piñeritos	** West Dog Island
Prickly Pear Island	West Seal Dog Island
Puerto Rico ¹	

Anolis cuvieri

Puerto Rico

* Vieques

¹ Also hybrids between *A. c. cristatellus* and *A. c. wileyae*.

Anolis desechensis

Desecheo

Anolis evermanni

Puerto Rico

Anolis gundlachi

Puerto Rico

Anolis krugi

Puerto Rico

Anolis monensis

Mona

Monito

Anolis occultus

Puerto Rico

Anolis poncensis

Puerto Rico

Anolis pulchellus

Algodones	Cayo Norte
Anegada	Cayo Ratones (near Hicacos)
Cabeza de Perro	Cayo Santiago
Caja de Muertos	Culebra
(Cayo Ahogado)	* Fallen Jerusalem
Cayo Batata	Greater Camanoe
Guana Island	Piñeros
Hicacos	Puerto Rico
Isleta Marina	* St. James
* Jost van Dyke	St. John
Little Jost van Dyke	St. Thomas
* Little St. James	Tortola
* Lovango Key	Vieques
Palominos	Virgin Gorda
Peter Island	* Water Island

Anolis roosevelti

* Culebra

Anolis stratulus

Beef Island (near Tortola)	Norman Island
Cayo Santiago	* Peter Island
* Congo Key	Piñeros
Culebra	Prickly Pear
Fallen Jerusalem	Puerto Rico
Ginger Island	St. John
Greater Camanoe	St. Thomas
Greater Thatch Island	* Savanna Island
Guana Island	Scrub Island
* Jost van Dyke	Tortola
Little Jost van Dyke	Vieques
* Little Saba (near St. Thomas)	Virgin Gorda
Marina Cay	* Water Island
Necker Island	

Cyclura cornuta

Mona

Cyclura pinguis

Anegada

Iguana iguana

* Guana Island	* St. Croix
* Hassel Island	* St. John
Hicacos (pers. com. S.D. Garber)	* St. Thomas
Peter Island	* Tortola
Puerto Rico	* Water Island

Teiidae*Ameiva alboguttata*

Mona

Ameiva desecheensis

Desecheo

Ameiva exsul

Algodones	(Levin's Rock)
Anegada	Little Camanoe
Beef Island	Little Hans Lollick
Blanquilla	Little Jost van Dyke
* Buck Island (near Tortola)	Little Saba (near St. Thomas)
Cabeza de Perro	Little St. James
Caja de Muertos	Lovango Key

- | | |
|-------------------|-----------------|
| * Cardona Key | Marina Cay |
| (Cayo Ahogado) | Mosquito Island |
| Cayo Batata | Necker Island |
| Cayo Lobos | Norman Island |
| Cayo Norte | Palominitos |
| Cayo Ratones | Palominos |
| Cayo Santiago | Peter Island |
| Cooper Island | Piñeros |
| Culebra | Platillo |
| Culebrita | Prickly Pear |
| Dead Man's Chest | Puerto Rico |
| Diablo | Ramos |
| * Dutchman's Cap | St. James |
| Eustatia | St. John |
| George Dog Island | St. Thomas |
| Ginger Island | Salt Island |
| Greater Camanoe | * Salt Key |
| Guana Island | Savanna Island |
| Hans Lollick | Scrub Island |
| Hassel Island | Tobago |
| Hicacos | Tortola |
| Inner Brass | Vieques |
| Isleta Marina | Virgin Gorda |
| Konyokí | Water Island |

Ameiva polops

- | | |
|----------------------------|-------------|
| Green Key (near St. Croix) | * St. Croix |
| Protestant Key | |

Ameiva wetmorei

- | | |
|-----------------|-------------|
| Caja de Muertos | Puerto Rico |
| Magueyes Island | |

Scincidae

Mabuya mabouya sloanei

- | | |
|---------------------------------|---|
| * Anegada | Mona |
| Buck Island (near St. Thomas) | ** Monito |
| Cayo Norte | Necker Island |
| * Culebra | Peter Island |
| * Culebrita | Puerto Rico |
| Dead Man's Chest | * St. John |
| ** Ginger Island | * St. Thomas |
| Hicacos | Salt Island |
| * Jost van Dyke | * Vieques (Perhaps now locally extinct) |
| * Little Saba (near St. Thomas) | Virgin Gorda |

Anguidae*Diploglossus pleii*

Puerto Rico

Gekkonidae*Hemidactylus brooki*

Puerto Rico

Hemidactylus mabouia

Culebra	St. Thomas
* Jost van Dyke	* Salt Island
Mona	Tobago
Peter Island	Tortola
Puerto Rico	Vieques
St. Croix	* Water Island
* St. John	

Phyllodactylus wirshingi

* Caja de Muertos	* Puerto Rico
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Sphaerodactylus beattyi beattyi

Buck Island (near St. Croix)	St. Croix
Green Key (near St. Croix)	

Sphaerodactylus beattyi seamani

* St. Croix

Sphaerodactylus gaigeae

Cayo Santiago	Puerto Rico
Piñeros	

Sphaerodactylus klauberi

Puerto Rico

Sphaerodactylus levinsi

Desecheo Island

Sphaerodactylus macrolepis ateles

Puerto Rico

Sphaerodactylus macrolepis grandisquamis

Algodones	Cayo Santiago
Cabeza de Perro	Puerto Rico
Cayo Batata	

Sphaerodactylus macrolepis guarionex

Puerto Rico

Sphaerodactylus macrolepis inigoi

* Cayo de Afuera	Vieques
* Cayo de Tierra	

Sphaerodactylus macrolepis macrolepis

Anegada	Buck Island (near St. Croix)
Bare Cactus Island	* Buck Island (near Tortola)
Beef Island	* Cayo Luis Peña
Big Cockroach	Cayo Norte
Botella	Chicken Island
* Buck Island (near St. Thomas)	Cockroach (near St. Thomas)
Cooper Island	Little Tobago
* Congo Key	Marina Cay
Culebra	Mosquito
Culebrita	Necker Island
Dead Man's Chest	Norman Island
East Geniquí	Peter Island
East Seal Dog	Prickly Pear
Eustatia	Sail Rock
Fallen Jerusalem	St. Croix
George Dog Island	St. John
Ginger Island	St. Thomas
Great Dog Island	Salt Island
Greater Camanoe	Sandy Cay (near Tortola)
Greater Thatch	Sandy Spit
Green Cay (near Tortola)	* Savanna Island
Guana Island	Scrub Island
Hans Lollick	Tobago
Jost van Dyke	Tortola
Little Camanoe	Villa del Mar
Little Hans Lollick	Virgin Gorda
Little Jost van Dyke	* Water Island
Little Saba	Watson Rock
* Little St. James	West Dog Island
Little Thatch Island	West Seal Dog Island

Sphaerodactylus macrolepis mimetes

Puerto Rico

Sphaerodactylus macrolepis phoberus

Puerto Rico

Sphaerodactylus macrolepis spanius

Puerto Rico

Sphaerodactylus macrolepis stibarus

Piñeros

Sphaerodactylus monensis

Mona

*Sphaerodactylus nicholsi nicholsi*Magueyes Island
Puerto RicoSpiny Butte
(Turramote Key)*Sphaerodactylus nicholsi townsendi*Blanquilla
Booby HatchHicacos
Isla Cabras (near Roosevelt
Rds., P.R.)

Caja de Muertos

Konyokí

* Cayo de Afuera (near Vieques)

MacKenzie Key

* Cayo de Tierra (near Vieques)

Palominos

Cayo Lobos

Piñeros

Cayo Ratones (near Hicacos)

Platillo

* Culebra

Puerto Rico

Diablo

Ramos

French Cap Key

Surprise Key

Grant Rock

Vieques

Sphaerodactylus parthenopion

Mosquito Island

Virgin Gorda

*Sphaerodactylus roosevelti*Caja de Muertos
Magueyes IslandPuerto Rico
* Vieques*Thecadactylus rapicaudus*

Necker Island

* St. Croix

AMPHISBAENIANS

Amphisbaenidae

Amphisbaena bakeri

Puerto Rico

Amphisbaena caeca

Puerto Rico

Amphisbaena fenestrata

- | | |
|----------------------|----------------|
| * Greater Camanoe | * St. Thomas |
| Little Jost van Dyke | * Tortola |
| * St. James | * Virgin Gorda |
| * St. John | |

Amphisbaena schmidtii

Puerto Rico

Amphisbaena xera

Caja de Muertos (called *A. caeca* Puerto Rico
by Heatwole et al. 1965)

SNAKES

Boidae*Epicrates inornatus*

Puerto Rico

Epicrates monensis

- | | |
|--------|-----------|
| * Mona | * Tortola |
|--------|-----------|

Colubridae*Alsophis portoricensis*

- | | |
|---------------------------------|----------------|
| Anegada | Mona |
| * Buck Island (near St. Thomas) | Mosquito |
| Cabeza de Perro | Necker Island |
| Caja de Muertos | Norman Island |
| Cayo Santiago | * Peter Island |
| * Cockroach (near St. Thomas) | Platillo |
| Culebra | Puerto Rico |
| Ginger Island | * St. John |
| Green Cay (near Tortola) | * St. Thomas |
| Guana Island | * Salt Island |

* Jost van Dyke
 * Little Saba
 Little Tobago

* Savanna Island
 * Vieques
 Virgin Gorda

Alsophis sancticrucis

* St. Croix

Arrhyton exiguum

Anegada
 Cayo Santiago
 * Culebra
 Greater Camanoe
 * Hassel Island
 Peter Island

Puerto Rico
 * St. John
 St. Thomas
 Tortola
 Virgin Gorda

Typhlopidae

Typhlops granti

Puerto Rico

Typhlops monensis

Mona

Typhlops richardi

Cayo Norte
 * Culebra
 Diablo
 Guana Island
 Little Hans Lollick
 Little Jost van Dyke
 Palominos

Puerto Rico
 * St. Croix
 * St. John
 * St. Thomas
 Surprise Key
 Tortola
 Virgin Gorda

Typhlops rostellata

Puerto Rico

TURTLES (excluding marine ones)

Emydidae

Chrysemys decussata stejnegeri

Puerto Rico

Testudinidae*Geochelone carbonaria*

- | | |
|--------------|----------------|
| * St. John | * Tortola |
| * St. Thomas | * Water Island |

ANURANS

Buфонidae*Bufo lemur*

Puerto Rico

Bufo marinus (introduced)

Algodones	Puerto Rico
Cayo Santiago	St. Croix
Culebra	Vieques

Bufo turpis

- * Virgin Gorda

Leptodactylidae*Eleutherodactylus antillensis*

Culebra	St. Thomas
Piñeros	Tortola
Puerto Rico	Vieques
St. Croix (introduced?)	Virgin Gorda
St. John	

Eleutherodactylus brittoni

Puerto Rico

Eleutherodactylus cochranae

- | | |
|-----------------|------------|
| * Hassel Island | St. Thomas |
| Puerto Rico | Tortola |
| St. John | |

Eleutherodactylus cooki

Puerto Rico

Eleutherodactylus coqui

Puerto Rico

Eleutherodactylus eneidae

Puerto Rico

Eleutherodactylus gryllus

Puerto Rico

Eleutherodactylus hedrecki

Puerto Rico

Eleutherodactylus karlschmidti

Puerto Rico

Eleutherodactylus lentus

St. Croix

St. Thomas

Eleutherodactylus locustus

Puerto Rico

Eleutherodactylus monensis

Mona

Eleutherodactylus portoricensis

Puerto Rico

Eleutherodactylus richmondi

Puerto Rico

Eleutherodactylus schwartzi

Great Dog

Tortola

St. Croix (introduced?)

Virgin Gorda

St. John

Eleutherodactylus unicolor

Puerto Rico

Eleutherodactylus wightmanae

Puerto Rico

Leptodactylus alibilabris

Algodones	Puerto Rico
Anegada	St. Croix
Cayo Santiago	St. John
Culebra	St. Thomas
Hicacos	Tortola
Piñeros	Vieques

Ranidae*Rana catesbeiana* (introduced)

Puerto Rico	Vieques (J.E. Cooper, pers. com.)
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Fauna of Islands

Algodones

<i>Ameiva exsul</i>	<i>Bufo marinus</i> (introduced)
<i>Anolis cristatellus cristatellus</i>	<i>Leptodactylus alibilabris</i>
<i>Anolis cristatellus wileyae</i>	<i>Sphaerodactylus macrolepis grandis-</i>
<i>Anolis pulchellus</i>	<i>quamis</i>

Anegada

<i>Alsophis portoricensis</i>	* <i>Cyclura pinguis</i>
<i>Ameiva exsul</i>	<i>Leptodactylus alibilabris</i>
<i>Anolis cristatellus wileyae</i>	* <i>Mabuya mabouya sloanei</i>
<i>Anolis pulchellus</i>	<i>Sphaerodactylus macrolepis macrolepis</i>
* <i>Arrhyton exigum</i>	

Bare Cactus Island

<i>Anolis cristatellus wileyae</i>	<i>Sphaerodactylus macrolepis macrolepis</i>
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Beef Island (near Tortola)

<i>Ameiva exsul</i>	<i>Anolis stratulus</i>
<i>Anolis cristatellus wileyae</i>	<i>Sphaerodactylus macrolepis macrolepis</i>

Big Cockroach

Sphaerodactylus macrolepis macrolepis

Blanguilla

Ameiva exsul *Sphaerodactylus nicholsi townsendi*
Anolis cristatellus wileyae

Booby Hatch

Anolis cristatellus wileyae *Sphaerodactylus nicholsi townsendi*

Botella Island

Anolis cristatellus wileyae *Sphaerodactylus macrolepis macrolepis*

Buck Island (near St. Thomas)

* *Alsophis portoricensis* * *Mabuya mabouya sloanei*
* *Anolis cristatellus wileyae* * *Sphaerodactylus macrolepis macrolepis*

Buck Island (near St. Croix)

Anolis acutus *Sphaerodactylus macrolepis macrolepis*
Sphaerodactylus beattyi beattyi

Buck Island (near Tortola)

Ameiva exsul * *Sphaerodactylus macrolepis macrolepis*

Cabeza de Perro

<i>Alsophis portoricensis</i>	<i>Anolis pulchellus</i>
<i>Ameiva exsul</i>	<i>Sphaerodactylus macrolepis</i>
<i>Anolis cristatellus wileyae</i>	<i>grandisquamis</i>

Caja de Muertos

<i>Alsophis portoricensis</i>	<i>Anolis cristatellus cristatellus</i>
<i>Ameiva exsul</i>	<i>Anolis pulchellus</i>
<i>Ameiva wetmorei</i>	* <i>Phyllodactylus wirshingi</i>
<i>Amphisbaena xera</i>	<i>Sphaerodactylus nicholsi townsendi</i>
<i>Anolis cooki</i>	<i>Sphaerodactylus roosevelti</i>

Cardona Key

Ameiva exsul * *Anolis cristatellus cristatellus*

Cayo Ahogado

(*Ameiva exsul*) (*Anolis pulchellus*)
(*Anolis cristatellus cristatellus*)

Cayo Batata

<i>Ameiva exsul</i>	<i>Anolis pulchellus</i>
<i>Anolis cristatellus cristatellus</i>	<i>Sphaerodactylus macrolepis grandis-</i> <i>quamis</i>

Cayo de Afuera

* *Sphaerodactylus macrolepis inigoi* * *Sphaerodactylus nicholsi townsendi*

Cayo de Tierra

* *Sphaerodactylus macrolepis inigoi* * *Sphaerodactylus nicholsi townsendi*

Cayo Lobos

<i>Ameiva exsul</i>	
<i>Anolis cristatellus wileyae</i>	<i>Sphaerodactylus nicholsi townsendi</i>

Cayo Luis Peña

* *Sphaerodactylus macrolepis macrolepis*

Cayo Norte

<i>Ameiva exsul</i>	<i>Mabuya mabouya sloanei</i>
<i>Anolis cristatellus wileyae</i>	<i>Sphaerodactylus macrolepis macrolepis</i>
<i>Anolis pulchellus</i>	<i>Typhlops richardi</i>

Cayo Ratones

<i>Ameiva exsul</i>	<i>Anolis pulchellus</i>
<i>Anolis cristatellus wileyae</i>	<i>Sphaerodactylus nicholsi townsendi</i>

Cayo Santiago

<i>Alsophis portoricensis</i>	<i>Arrhyton</i>
<i>Ameiva exsul</i>	<i>Bufo marinus</i> (introduced)
<i>Anolis cristatellus cristatellus</i>	<i>Leptodactylus albilabris</i>
<i>Anolis pulchellus</i>	<i>Sphaerodactylus gaigeae</i>
<i>Anolis stratulus</i>	<i>Sphaerodactylus macrolepis grandis-</i> <i>quamis</i>

Chicken Island

<i>Anolis cristatellus wileyae</i>	<i>Sphaerodactylus macrolepis macrolepis</i>
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Cockroach (near St. Thomas)

* <i>Alsophis portoricensis</i>	<i>Sphaerodactylus macrolepis macrolepis</i>
<i>Anolis cristatellus wileyae</i>	

Cooper Island

Ameiva exsul
Anolis cristatellus wileyae

Sphaerodactylus macrolepis

Congo Key

* *Anolis cristatellus wileyae*
* *Anolis stratulus*

**Sphaerodactylus macrolepis macrolepis*

Culebra

Alsophis portoricensis
Ameiva exsul
Anolis cristatellus wileyae
Anolis pulchellus
* *Anolis roosevelti*
Anolis stratulus
Arrhyton exiguum
Bufo marinus (introduced)

Eleutherodactylus antillensis
Hemidactylus mabouia
Leptodactylus albilabris
 * *Mabuya mabouya sloanei*
Sphaerodactylus macrolepis macrolepis
 * *Sphaerodactylus nicholsi townsendi*
 * *Typhlops richardi*

Culebrita

Ameiva exsul
Anolis cristatellus wileyae

* *Mabuya mabouya sloanei*
Sphaerodactylus macrolepis macrolepis

Dead Man's Chest

Ameiva exsul
Anolis cristatellus wileyae

Mabuya mabouya sloanei
Sphaerodactylus macrolepis macrolepis

Desecheo

Ameiva *desechensis*
Anolis *desechensis*

Sphaerodactylus levinsi

Diablo

Anolis cristatellus wileyae
Ameiva exsul

Sphaerodactylus nicholsi townsendi
Typhlops richardi

Dog Island

* *Anolis cristatellus wileyae*

Dutchman's Cap

Ameiva exsul

* *Anolis cristatellus wileyae*

East Geniqui

Sphaerodactylus macrolepis macrolepis

East Seal Dog

Anolis cristatellus wileyae *Sphaerodactylus macrolepis macrolepis*

Eustatia

Anolis cristatellus wileyae *Sphaerodactylus macrolepis macrolepis*
Ameiva exsul

Fallen Jerusalem

Anolis cristatellus wileyae *Anolis stratulus*
 * *Anolis pulchellus* *Sphaerodactylus macrolepis macrolepis*

French Cap Key

Sphaerodactylus nicholsi townsendi

George Dog Island

Ameiva exsul *Sphaerodactylus macrolepis macrolepis*
Anolis cristatellus wileyae

Ginger Island

Alsophis portoricensis *Anolis stratulus*
Ameiva exsul ***Mabuya mabouya sloanei*
Anolis cristatellus wileyae *Sphaerodactylus macrolepis macrolepis*

Grant Rock

Anolis cristatellus wileyae *Sphaerodactylus nicholsi townsendi*

Great Dog Island

* *Anolis cristatellus wileyae* *Sphaerodactylus macrolepis macrolepis*
Eleutherodactylus schwartzi

Greater Camanoe

Ameiva exsul *Anolis stratulus*
 * *Amphisbaena fenestrata* *Arrhyton exiguum*
Anolis cristatellus wileyae *Sphaerodactylus macrolepis macrolepis*
Anolis pulchellus

Greater Thatch Island

Anolis cristatellus wileyae *Sphaerodactylus macrolepis macrolepis*
Anolis stratulus

Green Key (near St. Croix)

Ameiva *polops*
Anolis *acutus*

Sphaerodactylus beattyi beattyi

Green Cay (near Tortola)

Alsophis portoricensis
Anolis cristatellus wileyae

Sphaerodactylus macrolepis macrolepis

Guana Island

Alsophis portoricensis
Ameiva exsul
Anolis cristatellus wileyae
Anolis pulchellus

Anolis stratulus
* *Iguana iguana*
Sphaerodactylus macrolepis macrolepis
Typhlops richardi

Hans Lollick

Ameiva exsul
Anolis cristatellus wileyae

Sphaerodactylus macrolepis macrolepis

Hassel Island

Ameiva exsul
* Anolis cristatellus wileyae
Arrhyton exiguum

* *Eleutherodactylus cochranae*
* *Iguana iguana*

Hicacos

Ameiva exsul
Anolis cristatellus wileyae
Anolis pulchellus
Iguana iguana (pers. com.
S.D. Garber)

Leptodactylus albilabris
Mabuya mabouya sloanei
Sphaerodactylus nicholsi townsendi

Inner Brass Island

Ameiva exsul

Anolis cristatellus wileyae

Isla Cabras (near Roosevelt Rds., P.R.)

Anolis cristatellus wileyae

Sphaerodactylus nicholsi townsendi

Isleta Marina

Ameiva exsul

Anolis cristatellus wileyae

Anolis cristatellus cristatellus A.c. cristatellus X A. c. wileyae

Anolis pulchellus

Jost van Dyke

- | | |
|---------------------------------|--|
| * <i>Alsophis portoricensis</i> | * <i>Hemidactylus mabouia</i> |
| * <i>Anolis pulchellus</i> | * <i>Mabuya mabouya sloanei</i> |
| * <i>Anolis stratulus</i> | <i>Sphaerodactylus macrolepis macrolepis</i> |

Konyokí

- | | |
|------------------------------------|---|
| <i>Ameiva exsul</i> | <i>Sphaerodactylus nicholsi townsendi</i> |
| <i>Anolis cristatellus wileyae</i> | |

Levin's Rock

(Ameiva exsul)

Little Camanoe

- | | |
|------------------------------------|--|
| <i>Ameiva exsul</i> | <i>Sphaerodactylus macrolepis macrolepis</i> |
| <i>Anolis cristatellus wileyae</i> | |

Little Hans Lollick

- | | |
|--------------------------|--|
| <i>Alsophis richardi</i> | <i>Anolis cristatellus wileyae</i> |
| <i>Ameiva exsul</i> | <i>Sphaerodactylus macrolepis macrolepis</i> |

Little Jost van Dyke

- | | |
|------------------------------------|--|
| <i>Ameiva exsul</i> | <i>Anolis stratulus</i> |
| <i>Amphisbaena fenestrata</i> | <i>Sphaerodactylus macrolepis macrolepis</i> |
| <i>Anolis cristatellus wileyae</i> | <i>Typhlops richardi</i> |
| <i>Anolis pulchellus</i> | |

Little Saba (near St. Thomas)

- | | |
|--------------------------------------|--|
| * <i>Alsophis portoricensis</i> | * <i>Anolis stratulus</i> |
| <i>Ameiva exsul</i> | * <i>Mabuya mabouya sloanei</i> |
| * <i>Anolis cristatellus wileyae</i> | * <i>Sphaerodactylus macrolepis macrolepis</i> |

Little St. James

- | | |
|--------------------------------------|--|
| <i>Ameiva exsul</i> | * <i>Anolis pulchellus</i> |
| * <i>Anolis cristatellus wileyae</i> | * <i>Sphaerodactylus macrolepis macrolepis</i> |

Little Thatch Island

Sphaerodactylus macrolepis macrolepis

Little Tobago

- | | |
|------------------------------------|--|
| <i>Alsophis portoricensis</i> | <i>Sphaerodactylus macrolepis macrolepis</i> |
| <i>Anolis cristatellus wileyae</i> | |

Long Island

Anolis cristatellus cristatellus

Lovango Key

*Ameiva exsul** *Anolis pulchellus** *Anolis cristatellus wileyae*

MacKenzie Key

Sphaerodactylus nicholsi townsendi

Magueyes Island

*Ameiva wetmorei**Sphaerodactylus nicholsi nicholsi**Anolis cristatellus cristatellus* *Sphaerodactylus roosevelti*

Marina Cay

*Ameiva exsul**Anolis stratulus**Anolis cristatellus wileyae**Sphaerodactylus macrolepis macrolepis*

Mona

*Alsophis portoricensis** *Epicrates monensis**Ameiva alboguttata**Hemidactylus mabouia**Anolis monensis**Mabuya mabouya sloanei**Cyclura cornuta**Sphaerodactylus monensis**Eleutherodactylus monensis**Typhlops monensis*

Monito

*Anolis monensis*** *Mabuya mabouya sloanei*

Mosquito Island

*Alsophis portoricensis**Sphaerodactylus macrolepis macrolepis**Ameiva exsul**Sphaerodactylus parthenopion**Anolis cristatellus wileyae*

Necker Island

*Alsophis portoricensis**Mabuya mabouya sloanei**Ameiva exsul**Sphaerodactylus macrolepis macrolepis**Anolis cristatellus wileyae**Thecadactylus rapicaudus**Anolis stratulus*

Norman Island

<i>Alsophis portoricensis</i>	<i>Anolis stratulus</i>
<i>Ameiva exsul</i>	<i>Sphaerodactylus macrolepis macrolepis</i>
<i>Anolis cristatellus wileyae</i>	

Palominitos

<i>Ameiva exsul</i>	<i>Typhlops richardi</i>
<i>Anolis cristatellus wileyae</i>	

Palominos

<i>Ameiva exsul</i>	<i>Anolis pulchellus</i>
<i>Anolis cristatellus wileyae</i>	<i>Sphaerodactylus nicholsi townsendi</i>

Peter Island

* <i>Alsophis portoricensis</i>	<i>Arrhyton exiguum</i>
<i>Ameiva exsul</i>	<i>Hemidactylus mabouia</i>
<i>Anolis cristatellus wileyae</i>	<i>Iguana iguana</i>
<i>Anolis pulchellus</i>	<i>Mabuya mabouya sloanei</i>
* <i>Anolis stratulus</i>	<i>Sphaerodactylus macrolepis macrolepis</i>

Piñeros

<i>Ameiva exsul</i>	<i>Leptodactylus albilabris</i>
<i>Anolis cristatellus wileyae</i>	<i>Sphaerodactylus gaigeae</i>
<i>Anolis pulchellus</i>	<i>Sphaerodactylus macrolepis stibarum</i>
<i>Anolis stratulus</i>	<i>Sphaerodactylus nicholsi townsendi</i>
<i>Eleutherodactylus antillensis</i>	

Piñeritos

Anolis cristatellus wileyae

Platillo (Morillito)

<i>Alsophis portoricensis</i>	<i>Anolis cristatellus cristatellus</i>
** <i>Ameiva exsul</i>	<i>Sphaerodactylus nicholsi townsendi</i>

Prickly Pear Island

<i>Ameiva exsul</i>	<i>Anolis stratulus</i>
<i>Anolis cristatellus wileyae</i>	<i>Sphaerodactylus macrolepis macrolepis</i>

Protestant Key

<i>Ameiva polops</i>	<i>Anolis acutus</i>
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Puerto Rico

<i>Alsophis portoricensis</i>	
<i>Ameiva exsul</i>	<i>Anolis stratulus</i>
<i>Ameiva wetmorei</i>	<i>Arrhyton exiguum</i>
<i>Amphisbaena bakeri</i>	<i>Bufo lemur</i>
<i>Amphisbaena caeca</i>	<i>Bufo marinus</i> (introduced)
<i>Amphisbaena schmidtii</i>	<i>Chrysemys decussata stejnegeri</i>
<i>Amphisbaena xera</i>	<i>Diploglossus pleii</i>
<i>Anolis cooki</i>	<i>Eleutherodactylus antillensis</i>
<i>Anolis cristatellus cristatellus</i>	<i>Eleutherodactylus brittoni</i>
<i>Anolis cristatellus wileyae</i>	<i>Eleutherodactylus cochranae</i>
<i>Anolis c. cristatellus</i> X <i>A. c. wileyae</i>	<i>Eleutherodactylus cooki</i>
<i>Anolis cuvieri</i>	<i>Eleutherodactylus coqui</i>
<i>Anolis evermanni</i>	<i>Eleutherodactylus eneidae</i>
<i>Anolis gundlacki</i>	<i>Eleutherodactylus gryllus</i>
<i>Anolis krugi</i>	<i>Eleutherodactylus hedrecki</i>
<i>Anolis occultus</i>	<i>Eleutherodactylus karlschmidtii</i>
<i>Anolis poncensis</i>	<i>Eleutherodactylus locustus</i>
<i>Anolis pulchellus</i>	<i>Eleutherodactylus portoricensis</i>
<i>Eleutherodactylus richmondi</i>	<i>Sphaerodactylus macrolepis ateles</i>
<i>Eleutherodactylus unicolor</i>	<i>Sphaerodactylus macrolepis grandisquamis</i>
<i>Eleutherodactylus wightmanae</i>	<i>Sphaerodactylus macrolepis guarionex</i>
<i>Epicrates inornatus</i>	<i>Sphaerodactylus macrolepis mimetes</i>
<i>Hemidactylus brooki</i>	<i>Sphaerodactylus macrolepis phoberus</i>
<i>Hemidactylus mabouia</i>	<i>Sphaerodactylus macrolepis spanius</i>
<i>Iguana iguana</i>	<i>Sphaerodactylus nicholsi nicholsi</i>
<i>Leptodactylus albilabris</i>	<i>Sphaerodactylus nicholsi townsendi</i>
<i>Mabuya mabouya sloanei</i>	<i>Sphaerodactylus roosevelti</i>
* <i>Phyllodactylus wirshingi</i>	<i>Typhlops granti</i>
<i>Rana catesbeiana</i> (introduced)	<i>Typhlops richardi</i>
<i>Sphaerodactylus gaigei</i>	<i>Typhlops rostellata</i>
<i>Sphaerodactylus klauberi</i>	

Ramos

<i>Ameiva exsul</i>	<i>Anolis cristatellus wileyae</i>
<i>Anolis cristatellus cristatellus</i>	<i>Sphaerodactylus nicholsi townsendi</i>

Sail Rock

Sphaerodactylus macrolepis macrolepis

St. Croix

- | | |
|--|--|
| * <i>Alsophis sancticrucis</i> | <i>Hemidactylus mabouia</i> |
| * <i>Ameiva polops</i> | * <i>Iguana iguana</i> |
| <i>Anolis acutus</i> | <i>Leptodactylus albilabris</i> |
| <i>Bufo marinus</i> (introduced) | <i>Sphaerodactylus beattyi beattyi</i> |
| <i>Eleutherodactylus antillensis</i> (introduced?) | * <i>Sphaerodactylus beattyi seamani</i> |
| <i>Eleutherodactylus lentus</i> | <i>Sphaerodactylus macrolepis macrolepis</i> |
| <i>Eleutherodactylus schwartzi</i> (introduced?) | * <i>Thecadactylus rapicaudus</i> |
| | * <i>Typhlops richardi</i> |

St. James

- | | |
|---------------------------------|--------------------------------------|
| <i>Ameiva exsul</i> | * <i>Anolis cristatellus wileyae</i> |
| * <i>Amphisbaena fenestrata</i> | * <i>Anolis pulchellus</i> |

St. John

- | | |
|--------------------------------------|--|
| * <i>Alsophis portoricensis</i> | <i>Eleutherodactylus cochranae</i> |
| <i>Ameiva exsul</i> | <i>Eleutherodactylus schwartzi</i> |
| * <i>Amphisbaena fenestrata</i> | <i>Geochelone carbonaria</i> |
| <i>Anolis cristatellus wileyae</i> | * <i>Hemidactylus mabouia</i> |
| <i>Anolis pulchellus</i> | * <i>Iguana iguana</i> |
| <i>Anolis stratulus</i> | <i>Leptodactylus albilabris</i> |
| * <i>Arrhyton exiguum</i> | * <i>Mabuya mabouya sloanei</i> |
| <i>Eleutherodactylus antillensis</i> | <i>Sphaerodactylus macrolepis macrolepis</i> |
| | * <i>Typhlops richardi</i> |

St. Thomas

- | | |
|------------------------------------|--|
| * <i>Alsophis portoricensis</i> | <i>Anolis pulchellus</i> |
| <i>Ameiva exsul</i> | <i>Anolis stratulus</i> |
| <i>Amphisbaena fenestrata</i> | <i>Arrhyton exiguum</i> |
| <i>Anolis cristatellus wileyae</i> | <i>Eleutherodactylus antillensis</i> |
| <i>Eleutherodactylus cochranae</i> | <i>Leptodactylus albilabris</i> |
| <i>Eleutherodactylus lentus</i> | * <i>Mabuya mabouya sloanei</i> |
| * <i>Geochelone carbonaria</i> | <i>Sphaerodactylus macrolepis macrolepis</i> |
| <i>Hemidactylus mabouia</i> | * <i>Typhlops richardi</i> |
| * <i>Iguana iguana</i> | |

Salt Island

- | | |
|------------------------------------|--|
| * <i>Alsophis portoricensis</i> | * <i>Hemidactylus mabouia</i> |
| <i>Ameiva exsul</i> | <i>Mabuya mabouya sloanei</i> |
| <i>Anolis cristatellus wileyae</i> | <i>Sphaerodactylus macrolepis macrolepis</i> |

Salt Key

- | | |
|-----------------------|--------------------------------------|
| * <i>Ameiva exsul</i> | * <i>Anolis cristatellus wileyae</i> |
|-----------------------|--------------------------------------|

Sandy Cay (near Tortola)

Anolis cristatellus wileyae *Sphaerodactylus macrolepis macrolepis*

Sandy Spit

Anolis cristatellus wileyae *Sphaerodactylus macrolepis macrolepis*

Savanna Island

* *Alsophis portoricensis* * *Anolis stratulus*
Ameiva exsul * *Sphaerodactylus macrolepis macrolepis*
* *Anolis cristatellus wileyae*

Scrub Island

Ameiva exsul *Anolis stratulus*
Anolis cristatellus wileyae *Sphaerodactylus macrolepis macrolepis*

Spiny Butte

Sphaerodactylus nicholsi nicholsi

Surprise Key

Anolis cristatellus wileyae *Typhlops richardi*
Sphaerodactylus nicholsi townsendi

Tobago

Ameiva exsul *Hemidactylus mabouia*
Anolis cristatellus wileyae *Sphaerodactylus macrolepis macrolepis*

Tortola

Ameiva exsul *Eleutherodactylus schwartzi*
* *Amphisbaena fenestrata* * *Epicrates monensis*
Anolis cristatellus wileyae * *Geochelone carbonaria*
Anolis pulchellus *Hemidactylus mabouia*
Anolis stratulus * *Iguana iguana*
* *Anolis sp.* (giant form) *Leptodactylus albilabris*
Arrhyton exiguum *Sphaerodactylus macrolepis macrolepis*
Eleutherodactylus antillensis *Typhlops richardi*
Eleutherodactylus cochranae

Turramote Key

(*Sphaerodactylus nicholsi nicholsi*)

Vieques

- | | |
|--------------------------------------|---|
| * <i>Alsophis portoricensis</i> | <i>Leptodactylus albilabris</i> |
| <i>Ameiva exsul</i> | * <i>Mabuya mabouya sloanei</i> (now probably locally extinct) |
| <i>Anolis cristatellus wileyae</i> | <i>Rana catesbeiana</i> (introduced) (J.E. Cooper, pers. comm.) |
| * <i>Anolis cuvieri</i> | <i>Sphaerodactylus macrolepis inigoi</i> |
| <i>Anolis pulchellus</i> | <i>Sphaerodactylus nicholsi townsendi</i> |
| <i>Anolis stratulus</i> | * <i>Sphaerodactylus roosevelti</i> |
| <i>Bufo marinus</i> (introduced) | |
| <i>Eleutherodactylus antillensis</i> | |
| <i>Hemidactylus mabouia</i> | |

Villa del Mar

- | | |
|------------------------------------|--|
| <i>Anolis cristatellus wileyae</i> | <i>Sphaerodactylus macrolepis macrolepis</i> |
|------------------------------------|--|

Virgin Gorda

- | | |
|------------------------------------|--|
| <i>Alsophis portoricensis</i> | * <i>Bufo turpis</i> |
| <i>Ameiva exsul</i> | <i>Eleutherodactylus antillensis</i> |
| * <i>Amphisbaena fenestrata</i> | <i>Eleutherodactylus schwartzi</i> |
| <i>Anolis cristatellus wileyae</i> | <i>Mabuya mabouia sloanei</i> |
| <i>Anolis pulchellus</i> | <i>Sphaerodactylus macrolepis macrolepis</i> |
| <i>Anolis stratulus</i> | <i>Sphaerodactylus parthenopion</i> |
| <i>Arrhyton exiguum</i> | <i>Typhlops richardi</i> |

Water Island

- | | |
|--------------------------------------|--|
| <i>Ameiva exsul</i> | * <i>Geochelone carbonaria</i> |
| * <i>Anolis cristatellus wileyae</i> | * <i>Hemidactylus mabouia</i> |
| * <i>Anolis pulchellus</i> | * <i>Iguana iguana</i> |
| * <i>Anolis stratulus</i> | * <i>Sphaerodactylus macrolepis macrolepis</i> |

Watson Rock

- Sphaerodactylus macrolepis macrolepis*

West Dog Island

- | | |
|---------------------------------------|--|
| ** <i>Anolis cristatellus wileyae</i> | <i>Sphaerodactylus macrolepis macrolepis</i> |
|---------------------------------------|--|

West Seal Dog Island

- | | |
|------------------------------------|--|
| <i>Anolis cristatellus wileyae</i> | <i>Sphaerodactylus macrolepis macrolepis</i> |
|------------------------------------|--|

Appendix IV. Distribution of the scorpion *Centruroides nitidus* and the spider *Gasteracantha tetracantha* on the Puerto Rican Bank

Centruroides nitidus

Anegada	Little Tobago
Beef Island	Magueyes
Big Hans Lollick	Marina Cay
Big Tobago	Mosquito Island
Broken Jerusalem	Necker Island
Caja de Muertos	Norman Island
Cayo Diablo	Palominos
Cayo Norte	Peter Island
Cooper Island	Piñeros
Desecheo	Prickly Pear
Eustatia	Puerto Rico
Fallen Jerusalem	Ramos
George Dog	St. Croix
Great Dog	St. John
Greater Camanoe	St. Thomas
Great Thatch Island	Salt Island
Guana Island	Scrub Island
Hicacos	Tortola
Jost van Dyke	Virgin Gorda
Little Hans Lollick	
Little Jost van Dyke	
Little Thatch Island	

Gasteracantha tetracantha

Anegada	Jost van Dyke
Beef Island	Little Camanoe
Big Hans Lollick	Little Hans Lollick
Big Tobago	Little Thatch Island
Cayo Diablo	Mosquito Island
Culebrita	Necker Island
Desecheo	Norman Island
Eustatia	Piñeros
George Dog	Puerto Rico
Ginger Island	Salt Island
Great Dog	Tortola
Greater Camanoe	Virgin Gorda
Great Thatch Island	



Fig. 2. Rainfall at various localities on the Puerto Rican Bank, 1960-1967. Data from Climatological Data Puerto Rico and Virgin Islands, Vols. 6-12 (1960-1967). Numbers above histograms indicate yearly totals.

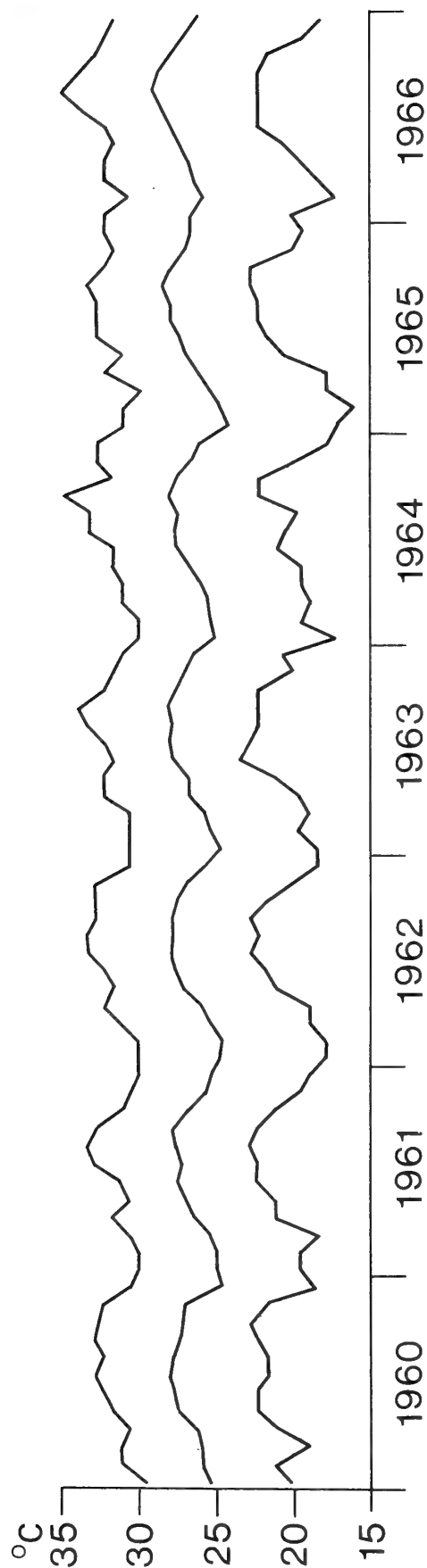


Fig. 3. Temperatures at Magueyes Island, Puerto Rico, 1960-1966. Upper line represents mean daily maxima, middle line the monthly means, and lower line the mean daily minima. Data from same source as that of Figure 2.

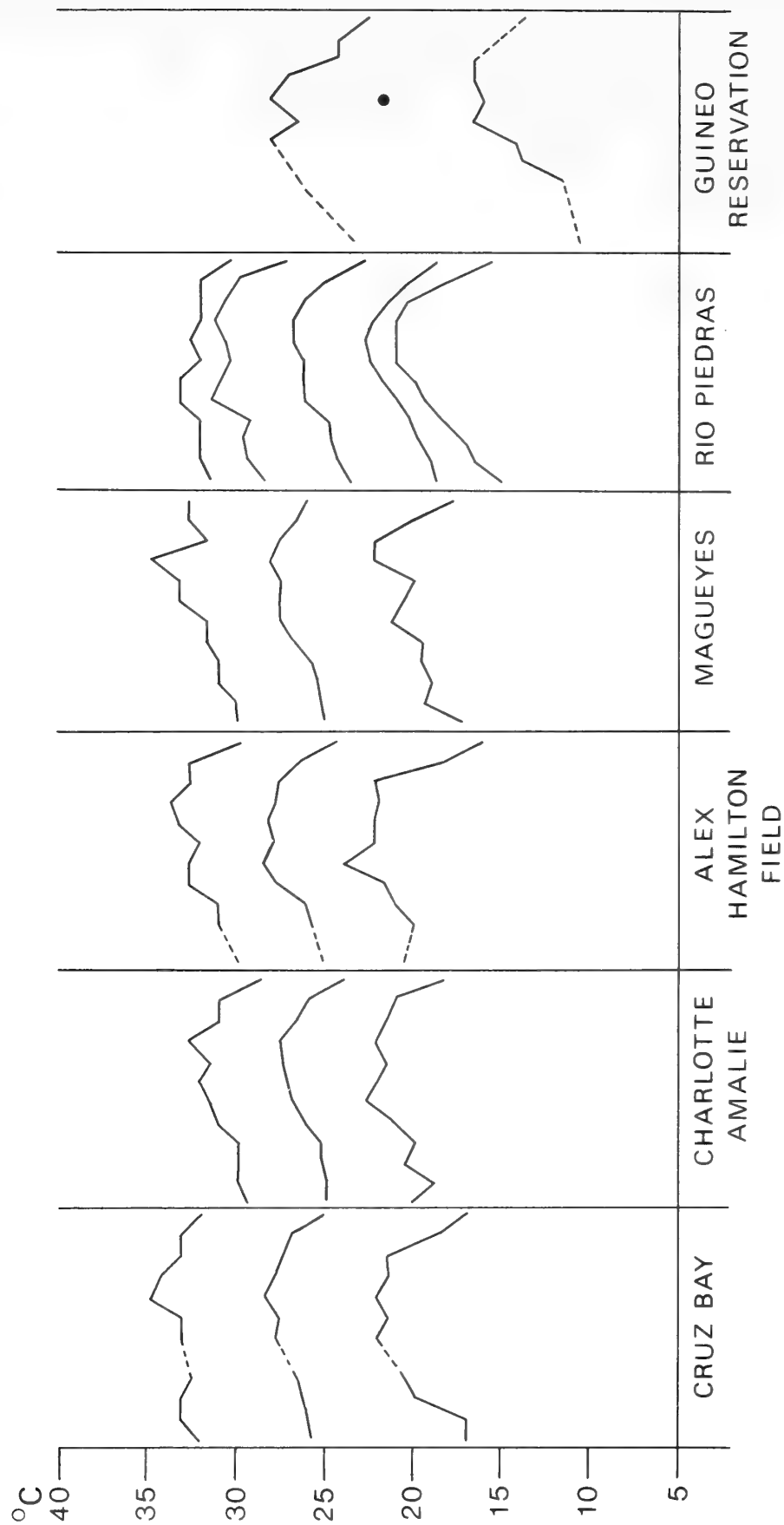


Fig. 4. Temperature at various localities on the Puerto Rican shelf during 1964. Cruz Bay, St. John; Charlotte Amalie, St. Thomas; Alexander Hamilton Field, St. Croix; Magueyes Island, Southwest P. R.; Rio Piedras, coastal P. R.; Guineo Reservation, upland P. R. Dotted lines indicate missing data, dot the August mean at Guineo Reservoir. The upper and lower lines for Rio Piedras represent monthly maxima and minima respectively. Other symbols as in Figure 3. Data from Climatological Data Puerto Rico and Virgin Island, Vol. 10 (1964).

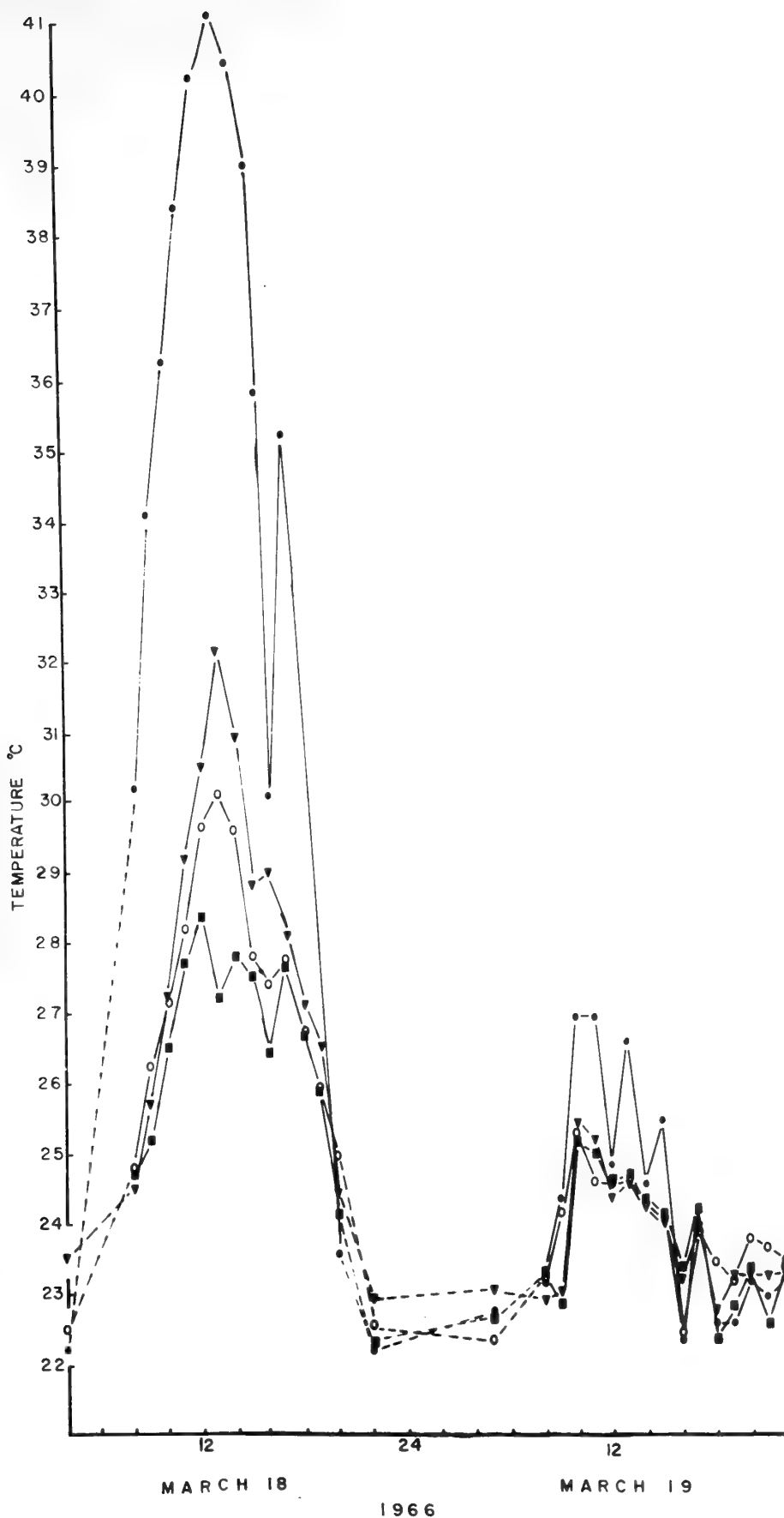


Fig. 5. Air and black bulb temperatures on Cayo Ahogado, P. R. Broken lines indicate intervals of more than 1 hour between measurements. Dots: black bulb temperatures 15 cm above the ground. Triangles: air, 1 cm above ground. Circles: air, 15 cm above ground. Squares: air, 1 m above ground

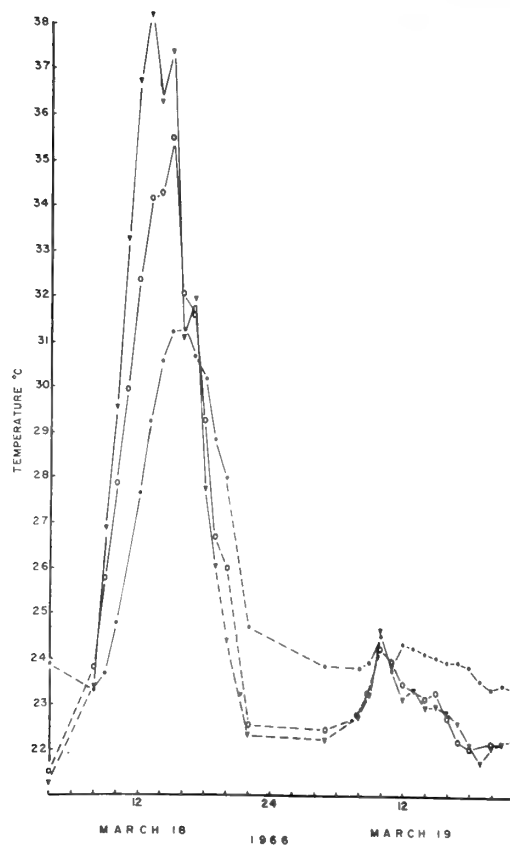
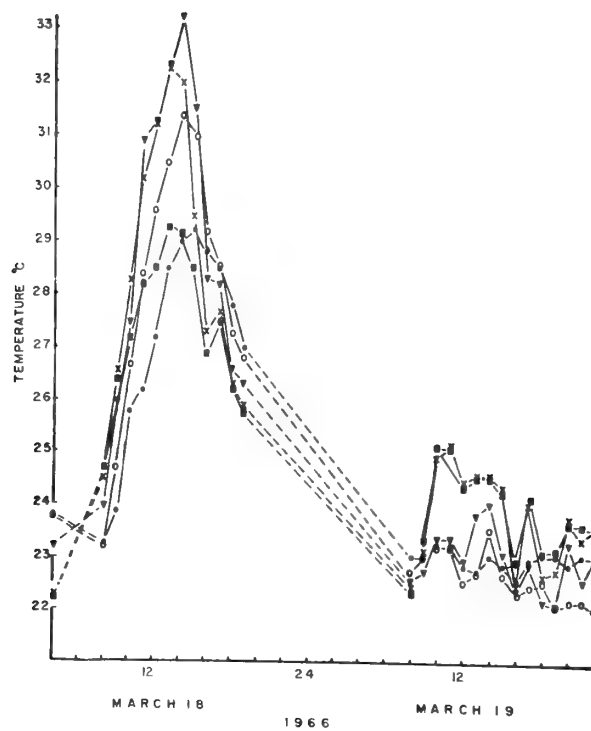


Fig. 6. Unshaded soil temperatures on Cayo Ahogado. Broken lines indicate intervals of more than one hour between measurements. Triangles: at soil surface. Circles: 1 cm deep. Dots: 5 cm deep.



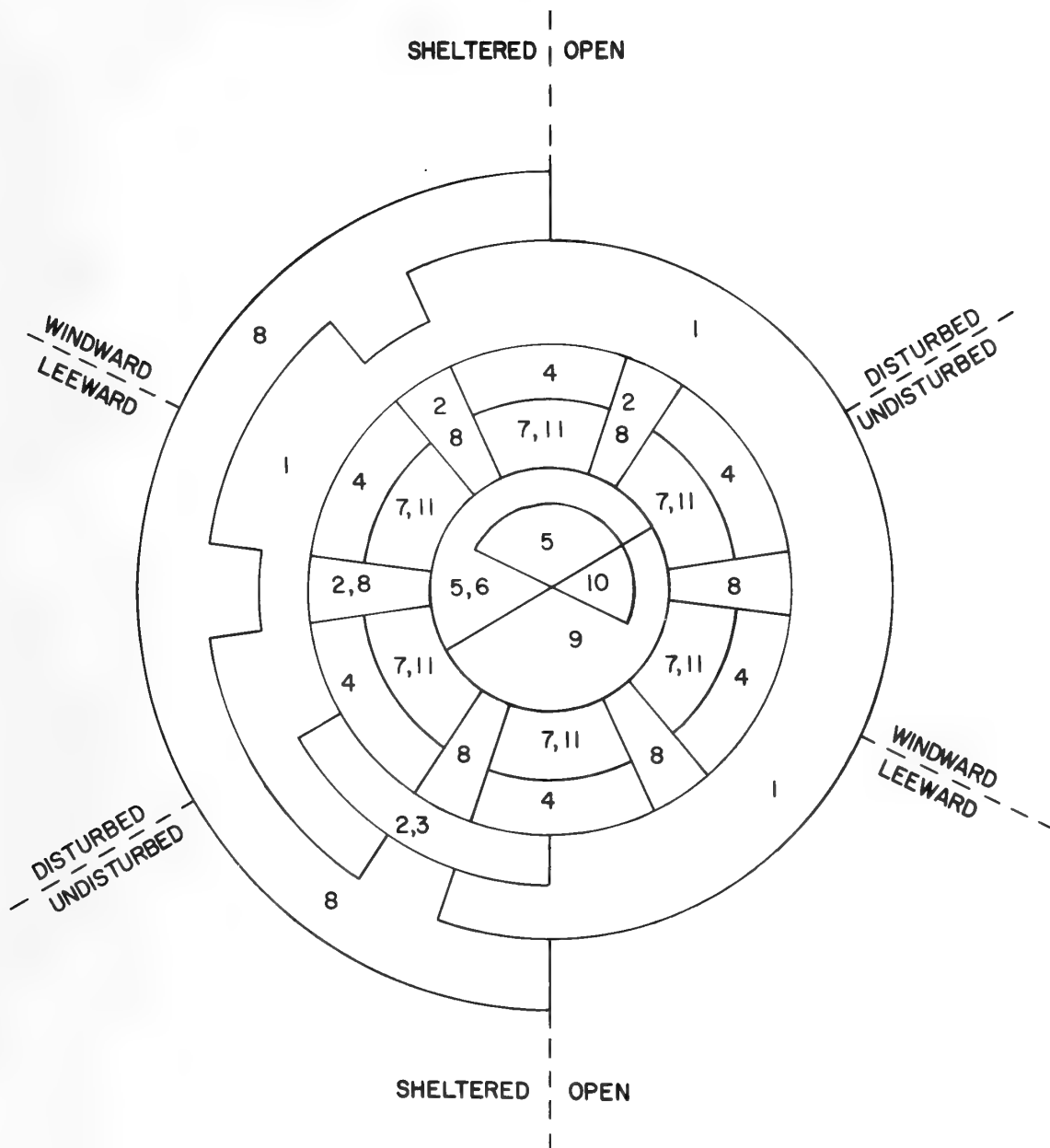


Fig. 8. Diagram-map of hypothetical island showing spatial relationships of numbered vegetation categories (described in text) to one another and to three environmental parameters. Three imaginary straight lines, whose termini are shown and labelled, divide the island into two conditions each of wind exposure, wave exposure, and disturbance. Elevation increases towards the center. As islands increase in area and elevation, concentric rings are added from the center, beginning with the most marginal ring not yet present, thus progressively expanding the rings already present toward the outside. Relative areas are not to scale; e.g., most of the area of a large, little-disturbed island might be covered by moist forest (10).

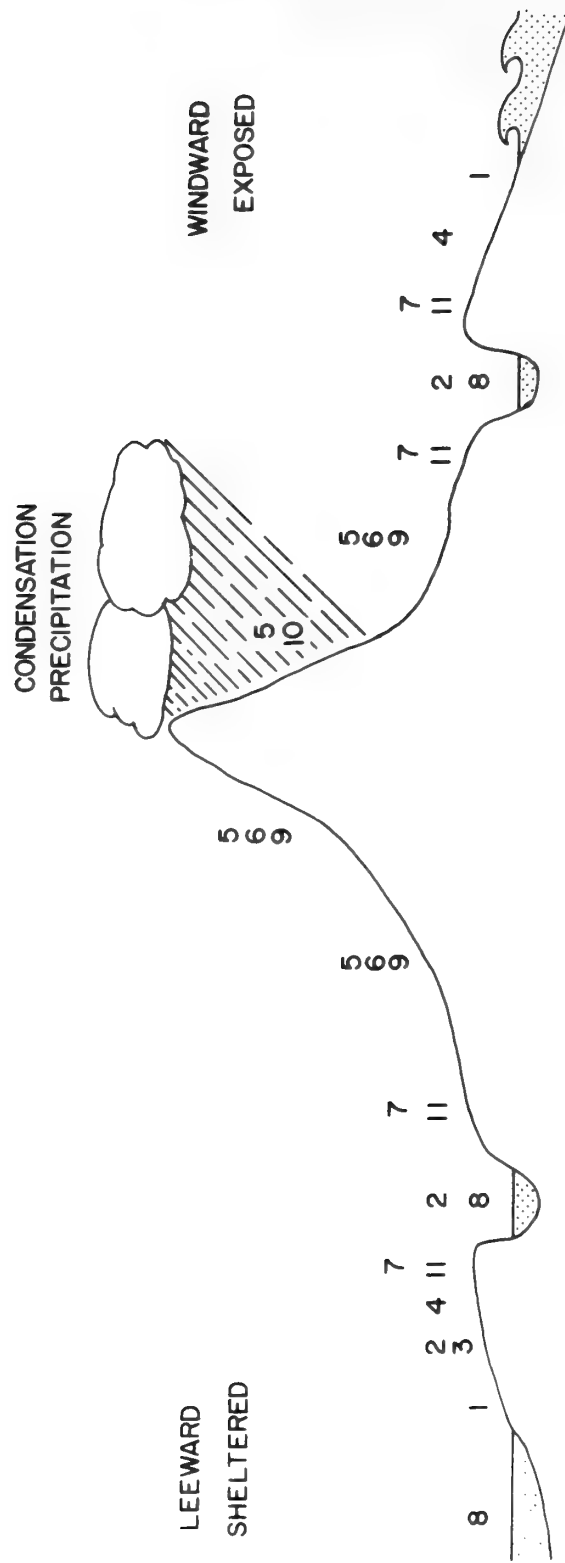
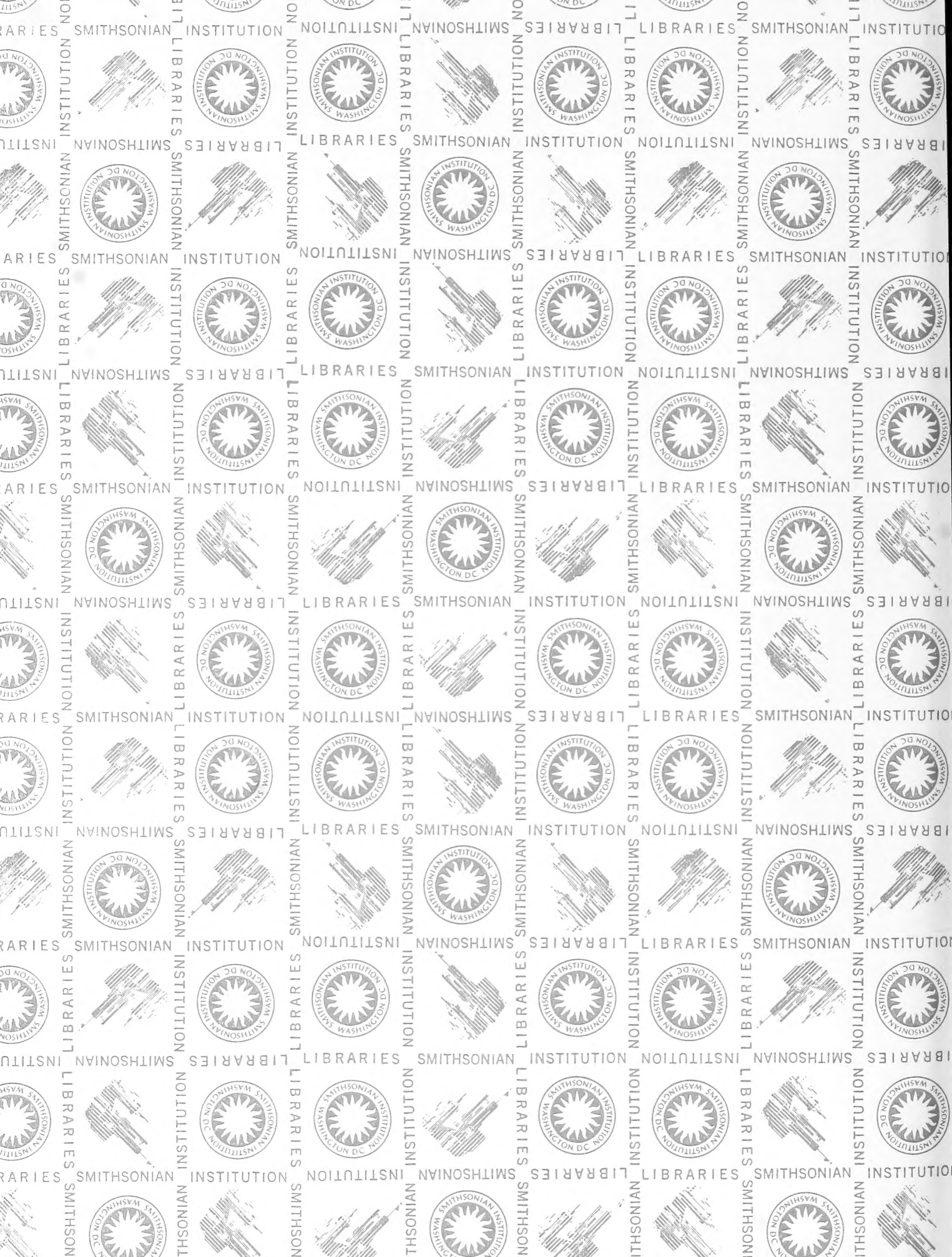
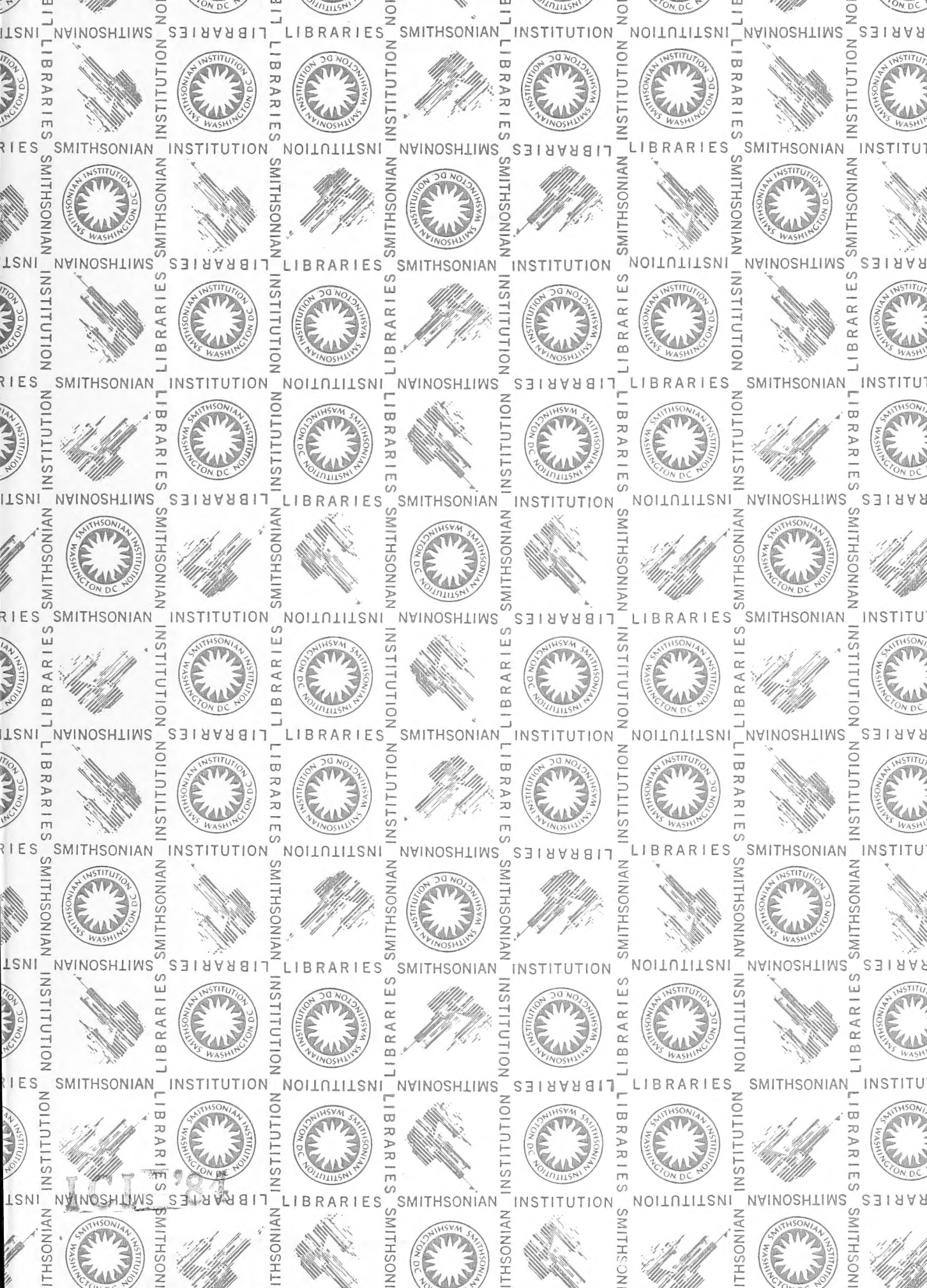


Fig. 9. Vertical section across a hypothetical island showing spatial relationships of numbered vegetation categories (described in text) to one another, distance from the sea, topography, elevation, wind direction, and wave exposure. Not to scale.





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